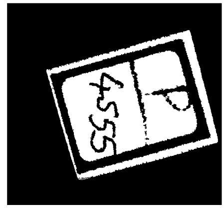
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SURVEYING: INSTRUMENTS AND METHODS

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for their own sake but in a large measure for the geometric principles involved. Contrary to usual practice, the transit is taken up before the level. This arrangement has been adopted after many years of experimentation in the author's own course. It enables the student to determine horizontal position at once, and as a result he is ready to make a complete survey at the earliest possible moment.

The basic surveying methods have been presented in detail. To shorten the text and at the risk of considerable criticism, only those procedures that the author believes to be the best practice have been included. Alternate procedures frequently found in use today have either been omitted or simply mentioned by name. The subjects covered in detail include the transit traverse, ties, stadia, bench-mark and profile leveling, establishing line and grade, and such additional material as is necessary to carry out these operations successfully and to finish the work in hand.

A number of problems are given at the end of each chapter. They are included so that a wide selection will be available to the instructor, not as a requirement for each student.

The course upon which this text is based has been found to be not only a satisfactory short course for general engineering instruction but also an excellent first course in surveying for civil-engineering students. The author first used a special introductory course for civil-engineering students and another course for academic students but obtained better results when this course was given to all.

The author is indebted to many persons and organizations for advice, encouragement, and assistance. Chief among these are Hugh C. Mitchell, formerly of the U.S. Coast and Geodetic Survey; Prof. Charles Roth of Newark College of Engineering; Prof. Herman J. Shea of Massachusetts Institute of Technology; Robert R. Singleton of Aero Service Corp.; Robert S. Rowe of Princeton University; Maj. Alden W. DeYoe, U.S. Coast Artillery; C. L. Berger & Sons, Inc.; Keuffel & Esser Co.; W. & L. E. Gurley; Eugene Dietzgen Co.; Fairchild Aircraft Div., Fairchild Engine & Airplane Corp.; and John A. Roebling's Sons Co.

PHILIP KISSAM.

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CHAPTER I

SURVEYING AND ITS APPLICATIONS

1. Definition. Surveying is the art of making relatively large precise measurements with a maximum of accuracy and with a minimum expenditure of time and labor.

2. Use. Surveying is used for two specific purposes. The first is to make maps, charts, and profiles and therefore to find the exact relative positions and elevations of existing objects. It is thus the basis of plans for nearly all engineering projects and a means of checking conformity to a plan. The second purpose is to lay out or mark the desired positions and elevations of objects to be built or placed as directed by a completed plan. In this capacity, surveying comprises the first step in any actual building process, and it is essential if the work is to be held to close tolerances or if any of the work is to be fabricated elsewhere.

3. Basis of Surveying. Surveying is based on method and on the two chief instruments employed, the transit and the level. By adroit use of the method and skillful use of the instruments, almost any measurement problem can be solved and the work facilitated. Conversely, it is difficult to solve any problem of relatively large measurement with reasonable facility without resorting to surveying methods and surveying instruments.

4. Importance to the Engineer. Surveying is obviously a fundamental element in civil engineering. Most civil-engineering projects are large in size and surveying presents the only means of planning or controlling them. But the method and instruments have been so developed that they usually present the best means of measurement for **any** work where bench-plate or optical techniques cannot be successfully employed. All types of engineers must use surveying to determine the possibilities of a plant site, to lay out plant equipment, to establish grades for liquid transfer, etc. But surveying methods and instruments also offer a tool that proves invaluable to the engineer who knows how to apply it to the small and complex measurements that are involved in manufacturing.

5. Surveying as a Means of Making Small Measurements. Although originally developed for field use, the transit and level are finding their way more and more into the shop (see Figs. 1, 2, 3). They are used to set up machinery, to align shafts, to establish close tolerances on

FIG. 1.—Berger instruments used to align a jig in an Aircraft plant. (*C. L. Berger & Sons, Inc., and Douglas Aircraft Co.*)

large jigs and fixtures, and to hold tolerances on large products like airplanes, railroad cars, and ships. Owing to their inherent precision, the measurements desired are usually obtained more quickly as well as more accurately with surveying instruments than by other means. The advantages to be gained by the use of surveying instruments have become particularly evident during the Second World War, and many new techniques have been developed around them.

FIG. 2.—A Y level in use at a Boeing plant. (*Boeing Aircraft Co.*)

6. Advantages of Surveying Instruments. Surveying instruments have certain advantages not found in most measuring devices. They are listed below.

1. Use of gravity. Gravity is used as a reference direction. The instruments are therefore self-aligning to a horizontal plane and yet free from the restrictions of the bench plate.

2. Optical sights. Optical sights with magnification are used instead of straightedges or wires. With the optical sight used in an ordinary transit, it is possible to hold a line straight to within ± 0.005 inch for 50 feet or to ± 0.001 inch for 10 feet.

3. Accurate angles. Angles can be set off within 30 seconds of arc or measured within 6 seconds with an ordinary transit.

4. Accurate levels. Differences in elevation of 0.01 inch can be observed between points 100 feet apart with an ordinary level.

5. Inherent adjustment. Surveying instruments are designed so that they may be used to test themselves, and they can be adjusted to eliminate any errors that these tests disclose. Surveying instruments are thus self-calibrating.

7. Surveying Techniques. To utilize the possibilities of surveying instruments, surveying methods must be thoroughly understood. The standard procedures that have been developed through the years nearly always produce the most accurate results in the shortest time and

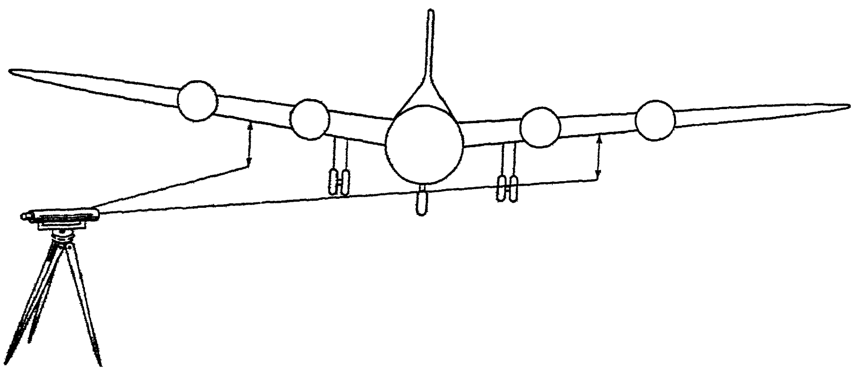


FIG. 3.—Airplanes are leveled by surveying instruments. Here gauge points have been incorporated under wings for this purpose.

with a minimum of opportunity for mistakes. These procedures are based on the fundamental principles of accurate measurement and are designed to meet the necessity for speed. An engineer does well to familiarize himself with these methods, for they not only give him an understanding of proper measurement procedure but also offer a basis for the design of methods to solve the particular measurement problems that may confront him.

8. Geometry of the Instruments. The geometric relationships that must be maintained in a transit are always present in any angle-measuring device. It is impossible safely to establish any angle-measurement procedure without a thorough understanding of the transit.

9. The level instrument is based on a principle of determining the direction of gravity that has almost universal application. It should be thoroughly understood both for designing other instruments and for successful use of the instrument itself.

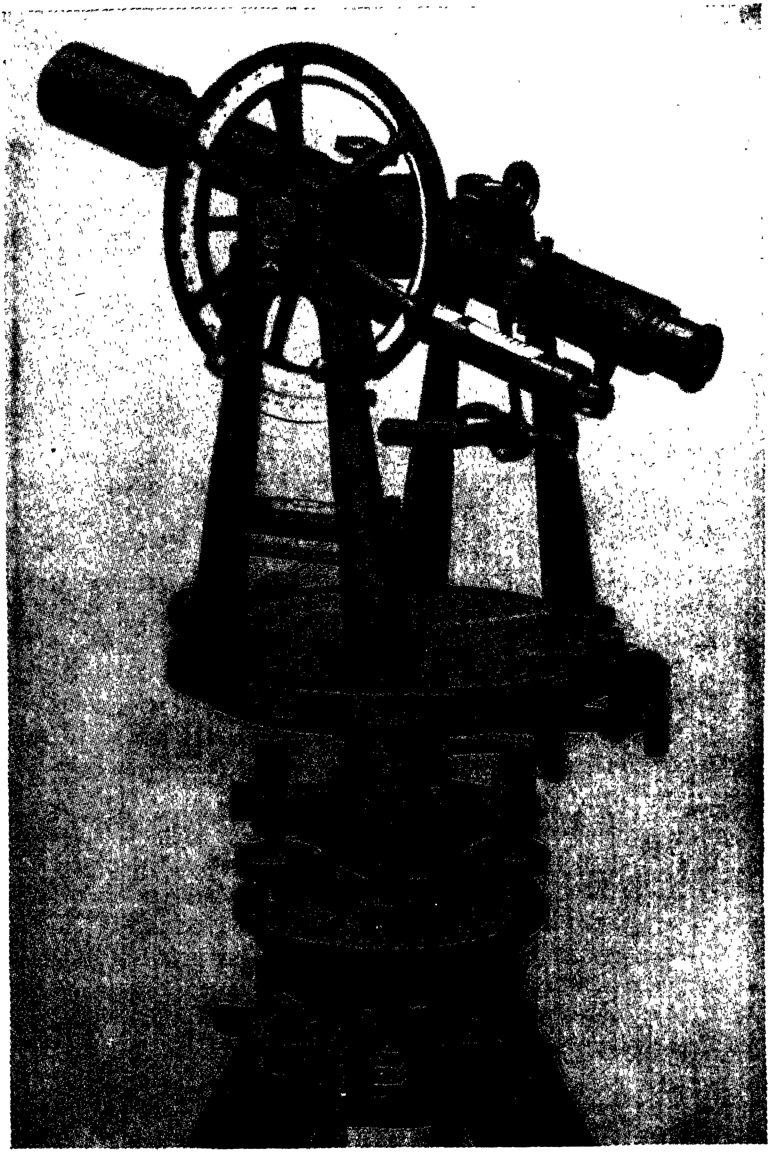


Fig. 4.—A Berger engineer's transit. (*C. L. Berger & Sons, Inc.*)

10. The Purpose of This Textbook. This book is designed to demonstrate as briefly as possible the surveying methods and instruments that are applicable to small areas. It therefore deals with the basic principles of surveying and is chiefly concerned with the understanding and the use of surveying instruments. It is intended to give the reader a complete concept of what surveying will do and to make it possible for him to map small areas, lay out construction details, and effectively utilize surveying for any measurement problem he may encounter in the field or in the shop.

CHAPTER II

THE SURVEYING METHOD

11. The surveying method is based on certain elements that facilitate operations and increase the accuracy of the work. These elements are described in the following paragraphs.

12. Gravity as a Reference Direction. The direction of gravity is used as a reference for all measurements. By **vertical** is meant the direction of gravity, and by **horizontal** is meant the direction perpendicular to gravity. Since the earth's surface is not a plane,[1] the direction of gravity is different at every position on the earth's surface.

13. The effect of the differences in the direction of gravity on horizontal measurements is so slight within a radius of 12 miles or so that it is almost impossible to measure it. For all small surveys, therefore, the curvature of the earth is neglected in the use of horizontal measurements. Plane geometry and plane trigonometry are used for the reduction of results, and such a survey is said to be a plane survey. It is the only type of survey covered in this text. When spherical trigonometry or elliptical formulas are used, the survey is called a **geodetic survey.**

14. Measurements Made. Measurements are made of only four types of dimensions. They are (1) **horizontal lengths**; (2) **vertical lengths**; (3) **horizontal angles**; (4) **vertical angles.**

15. Horizontal Length. A length measured horizontally throughout that does not change in horizontal direction is called a **horizontal length** or **distance.** Sometimes a distance is measured on a slope and immediately reduced to the horizontal equivalent (Fig. 1).

16. Vertical Length. A vertical length is measured along the direction of gravity and is equivalent to a difference in height.

17. Horizontal Angle. A horizontal angle is an angle measured in a plane that is horizontal at the vertex, i.e., at the point of measurement. When a horizontal angle is measured between points that do not lie in this plane, it is measured between the perpendiculars extended to this plane from these points (Fig. 2).

18. Vertical Angle. A vertical angle is sometimes called the **altitude angle, angle of elevation,** or **site angle.** The vertical angle of a

[1] It is nearly an oblate spheroid, i.e., the solid generated by an ellipse rotated on its minor axis.

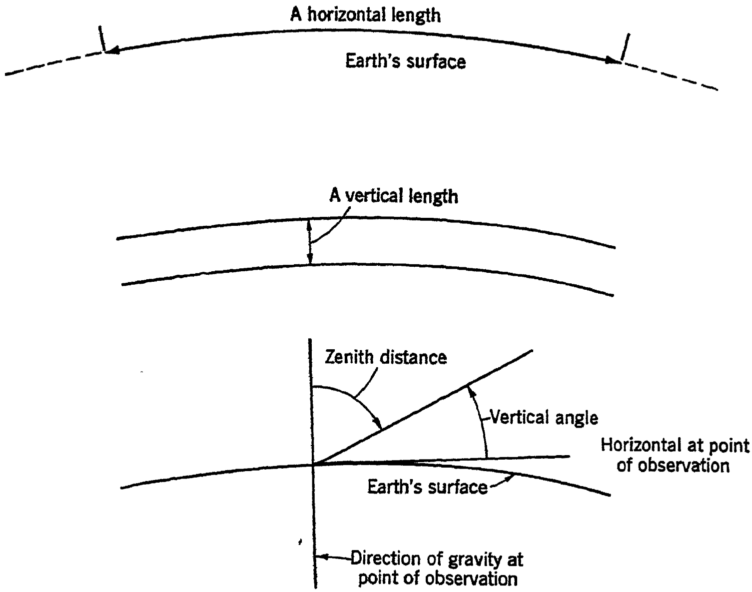
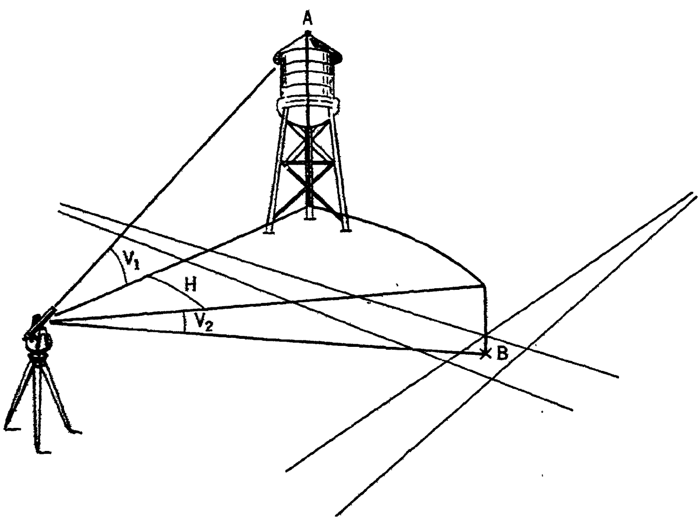


Fig. 1.—Dimensions measured.



H is the horizontal angle between A and B
V_1 is the plus vertical angle from the transit to A
V_2 is the minus vertical angle from the transit to B

Fig. 2.—Horizontal and vertical angles.

point is measured in a plane that is vertical at the point of observation and contains the point. Vertical angles are always measured up or down from the horizontal. Those measured upward are called **plus,** and those

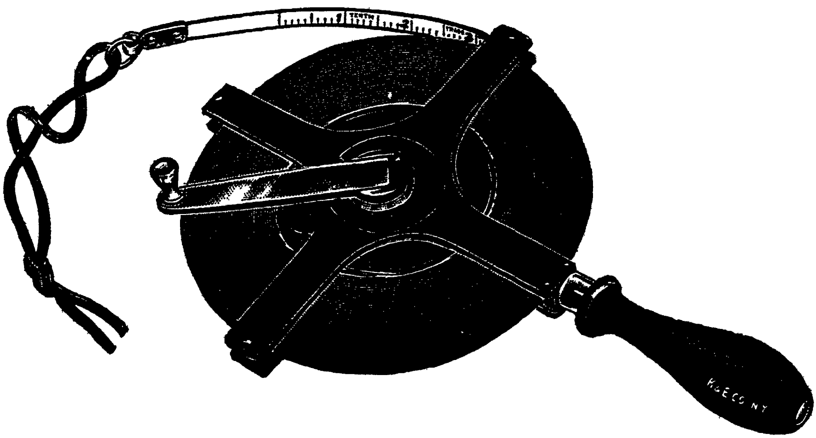


FIG. 3.—Surveying tapes are graduated in feet and decimals of a foot. (*Keuffel & Esser Co.*)

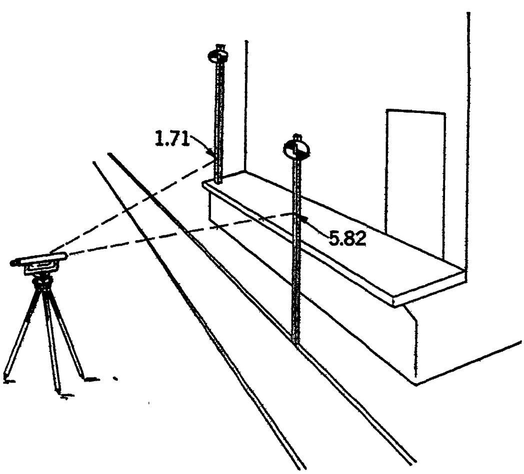


FIG. 4.—Measuring a difference in height between a rail and a platform. Difference is 5.82 − 1.71 = 4.11.

measured downward are called **minus.** Sometimes the complement of the vertical angle is measured. This is the angle from the vertical above the point of the observation, i.e., the **zenith,** down to the point. Such an angle is called a **zenith distance.**

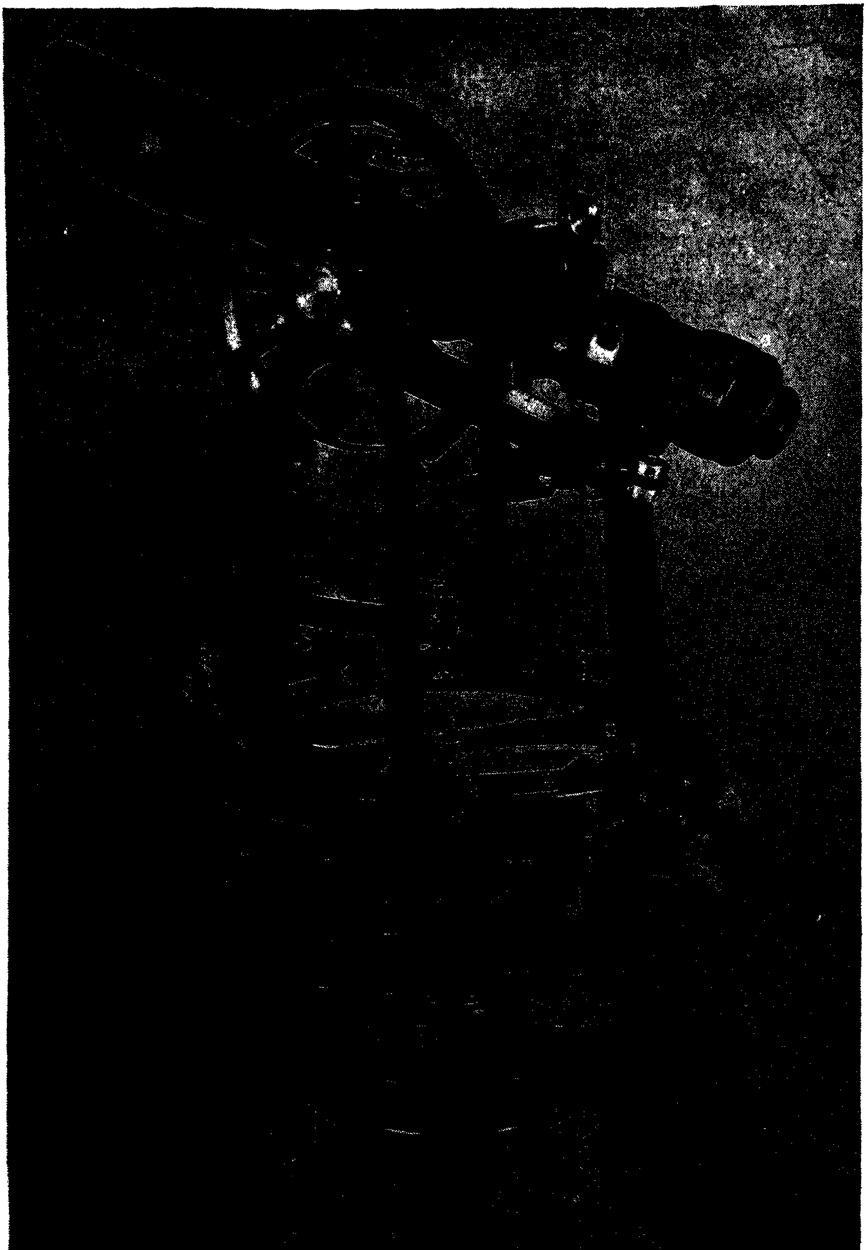


FIG. 5.—A Keuffel & Esser engineer's transit. (*Keuffel & Esser Co.*)

19. Measurement of Horizontal Lengths. Horizontal lengths are usually measured with steel tapes, usually graduated in hundredths of a foot, seldom in inches (see Fig. 3).

20. Measurement of Vertical Lengths. Vertical lengths are usually measured with wooden rods held vertically and graduated in hundredths of a foot. The level instrument or its equivalent is used to observe the rods. A level consists of a telescopic line of sight, which can be made horizontal by an attached sensitive spirit level. The instrument

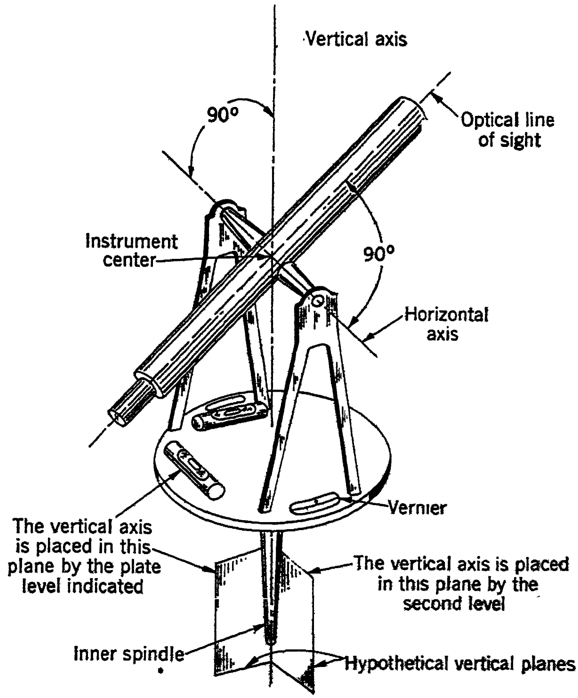


FIG. 6.—Transit essentials. Schematic diagram of an alidade.

can be turned in various directions around a stationary vertical axis. The differences in the readings on the rods are the differences in height of the points upon which the rods are placed (see Fig. 4).

21. Measurement of Horizontal and Vertical Angles. Horizontal and vertical angles are usually measured with a transit. A transit consists essentially of an optical line of sight, which is perpendicular to and supported on a horizontal axis. The horizontal axis is perpendicular to a vertical axis about which it can rotate. Spirit levels are used to make the vertical axis coincide with the direction of gravity. Graduated circles with verniers are used to read the angles (Figs. 5 and 6).

22. Designation of Horizontal Angles. Horizontal angles are designated according to a system that differs slightly from the method used in geometry. The system is introduced so that it is possible to designate exactly which angle is measured. Figure 7 illustrates the surveying method of designating horizontal angles.

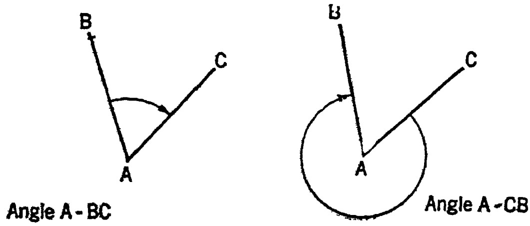


FIG. 7.—Method of designating angles. Clockwise measurement is always assumed. The designation shows which of the two angles at A is actually measured.

23. Measurement of Horizontal Position. The relative horizontal positions of points are usually determined by traverses or by triangulation. A traverse consists of the measurement of a series of horizontal lengths called **courses** and the horizontal angles between these

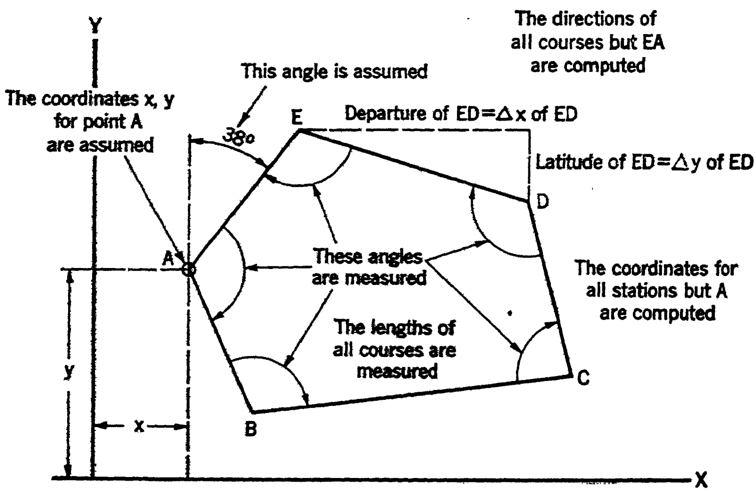


FIG. 8.—Method of establishing a coordinate system.

courses. Triangulation consists of the measurement of the angles of a series of connected triangles. At least one side of one triangle is measured. In both cases the final results are computed by trigonometry.

24. The results of a horizontal survey are best expressed by rectangular coordinates. One of the courses, or sides, is given a direction with

respect to north, by measurement or assumption, and the directions of the other lines are computed from the measured angles. The direction used for north thus fixes the orientation of the coordinate system with respect to the survey courses (see Fig. 8).

25. Direction. The directions of the sides, or courses, are expressed either by **azimuths** or by **bearings.** An azimuth is ordinarily a clockwise horizontal angle from a reference direction, usually north. South is usually used for geodetic surveys that cover great areas. A bearing is the angle from the north or south, **whichever is nearest,** with the added

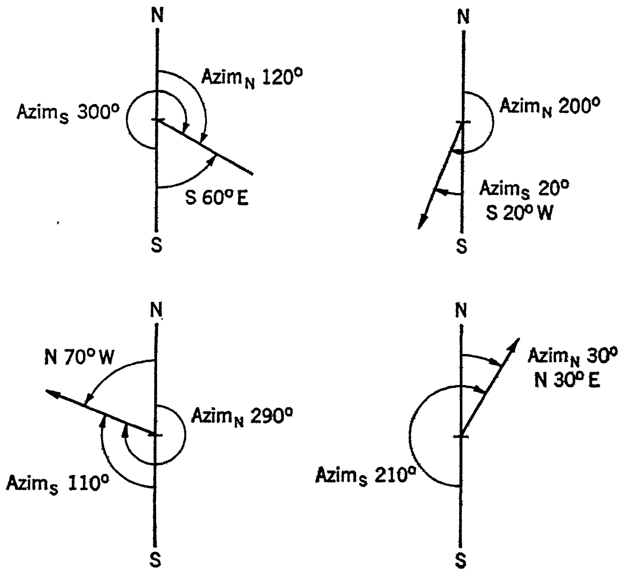


FIG. 9.—Methods of expressing direction. Equivalent azimuths and bearings.

designation of east or west, whichever applies. A bearing can never be greater than 90 deg. For example, the following four directions are expressed by these three methods (see Fig. 9):

Azimuth$_n$		Azimuth$_s$		Bearing
120°	=	300°	=	S 60° E
200°	=	20°	=	S 20° W
290°	=	110°	=	N 70° W
30°	=	210°	=	N 30° E

26. The opposite direction to the one stated is often called a **back direction.** The back direction of a line can be found by adding ± 180 deg to the forward direction. When bearings are used, this results

in merely changing both letters. For example, the back bearing of S 27°10′ E is N 27°10′ W, etc.

27. Position. The coordinates used are called **north** and **east** or y and x. North, or y, ordinates are measured northerly from an east-west line, or X axis. East, or x, abscissas are measured easterly from a north-south line, or Y axis. To establish them, the coordinates of one of the angle points are arbitrarily chosen. The coordinates of the other points are computed by trigonometry. The coordinates of the starting point

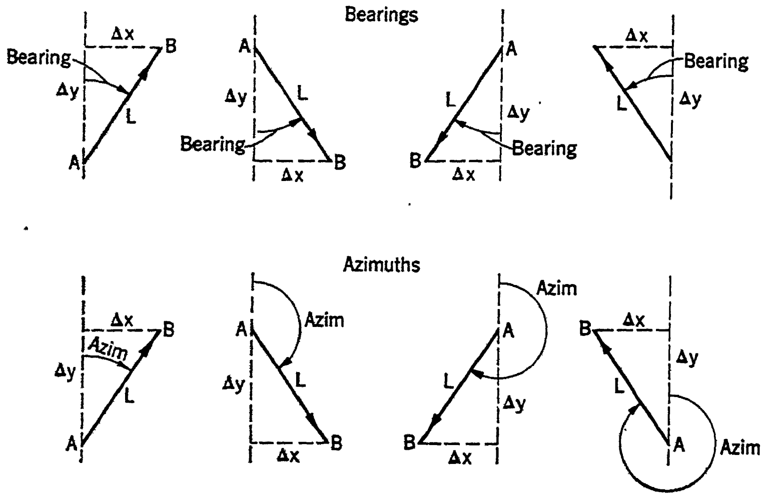


FIG. 10.—Computation of latitudes and departures. In every case

$$\frac{\Delta y}{L} = \cos \text{ direction} \qquad \Delta y = L \cos \text{ direction}$$

$$\frac{\Delta x}{L} = \sin \text{ direction} \qquad \Delta x = L \sin \text{ direction}$$

where Δy = latitude of AB
Δx = departure of AB
L = length of AB

should be so chosen that there will be no minus coordinates, i.e., the whole survey will lie in the northeast quadrant. Every line has a Δy called **a latitude** and a Δx called **a departure** (see Fig. 8). The latitude of a line is equal to the product of the length of the line multiplied by the cosine of its direction. The departure of a line is equal to the product of its length multiplied by the sine of its direction (see Fig. 10). A marked point showing horizontal position is called a **station,** usually abbreviated to Sta.

28. Vertical Position. The relative vertical positions of points are determined by a series of level observations. Since the line of sight of the

level is horizontal at each observation, the reference surface is made up of very short horizontal lines, or very nearly a curved surface everywhere perpendicular to gravity.

29. It is easier to refer the results of a level survey to a **standard datum.** Often mean sea level is used. The vertical heights above the standard datum are called **elevations.** Sometimes the standard datum surface is called a datum **plane,** even though the surface is curved. A marked point of known elevation is called a **bench mark,** usually abbreviated to B.M. (see Fig. 11).

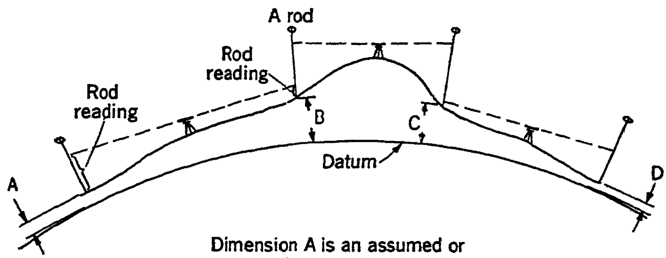


FIG. 11.—Principle of vertical position, or elevation.

30. Errors. It has been shown that surveying consists in making many measurements. When measurements are made, the results always contain errors, for no measurement can be perfect. There are three general types of errors, **accidental errors, systematic errors,** and **blunders.**

31. Accidental Errors. Accidental errors are the type of errors that represent the limit of the instruments, equipment, or skill in the determination of a value. Their sign and size are accidental, and they obey the laws of chance. With repeated measurements they have a tendency to cancel. Gauss has shown that, when a measurement depends on the sum of individual determinations, the accidental error in the final result varies with the square root of the number of individual measurements.

32. Systematic Errors. Systematic errors are the type of errors that are caused by some bias in the instrument, equipment, or procedure. Under the same conditions they are always of the same size and sign. A measuring tape that is the wrong length introduces a systematic error.

33. Blunders. Blunders are mistakes that are not the result of lack of judgment, skill, or ability.

34. Accuracy and Precision. Since no measurement is perfect, the results obtained are qualified by some measure of **accuracy.** Usually

this is estimated by a comparison of two or more independent measurements. When the accuracy is to be increased, greater **precision** must be used in the instruments, the methods, and the observations. Precision therefore can be defined as the degree of perfection **used** in the instruments, methods, and observations. Accuracy is the degree of perfection **obtained.**

35. High precision is costly but necessary for high accuracy. The chief art of surveying is to obtain the data required, with the degree of accuracy desired, at the lowest cost.

36. The degree of accuracy of a horizontal measurement is usually expressed as a ratio of the error to the total distance measured. For example, if an error of 0.18 feet were made in measuring 577.80 feet, the accuracy is expressed as follows:

$$\frac{0.18}{577.80} = 1/3{,}210$$

Ordinary measurement with a steel tape gives an accuracy of about 1 part in 3,000.

ORDER OF ACCURACY DEFINED BY BOARD OF SURVEYS AND MAPS OF THE FEDERAL GOVERNMENT, MAY 9, 1933

Type of survey	Type of error	Limits of error Order of accuracy			
		First	Second	Third	Fourth
Triangulation	Maximum angular closure per triangle	3″	5″	10″	No appreciable error in resulting map
	Average angular closure per triangle	1″	3″	5″	
	Error in length of base as computed through triangles after angles are adjusted	1/25,000	1/10,000	1/5,000	
	Probable error* of base measurement	1/1,000,000	1/500,000	1/200,000	
Traverse	Position closure after angles are adjusted	1/25,000	1/10,000	1/5,000	
Leveling	Error of closure, ft, divided by square root of distance leveled in miles	0.012	0.025	0.050	

* Probable error = 0.6745

where n = number of measurements
Σv^2 = sum of the squares of the quantities by which each measurement differs from the mean of the measurements.

37. The degree of accuracy of leveling is expressed as a ratio of the feet of error to the square root of the miles traversed. For example, ordinary leveling should not exceed

$$0.05 \text{ foot } \sqrt{\text{miles}}$$

An error of 0.20 foot in 9 miles would indicate too low an accuracy by this standard, since the allowable limit of accuracy is 0.15 foot.

38. The Solution of a Complete Surveying Problem. The method employed of attacking a problem is **always the same** and applies to all engineering projects. It is often called the **engineering approach.** It can be best explained by an illustration. Consider for this illustration

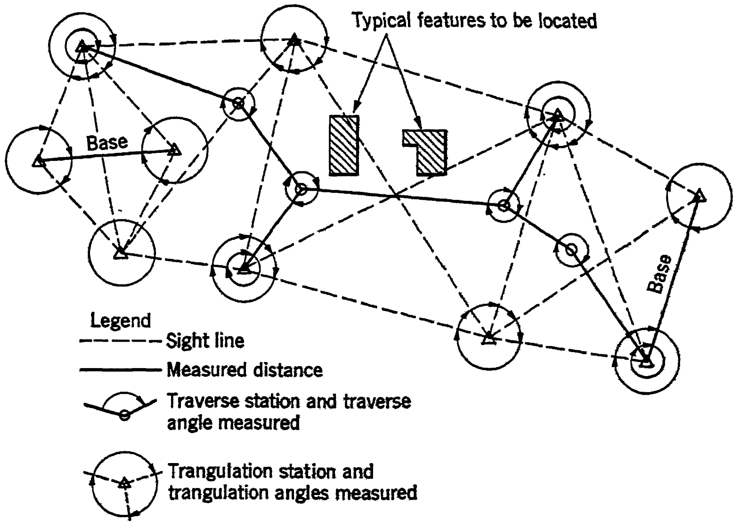


FIG. 12.—A horizontal control system showing a triangulation system and traverses closing on it.

the process of constructing a hydroelectric power plant. There are five steps in the method, as follows: (1) reconnaissance; (2) preliminary survey; (3) map; (4) plan; (5) location survey.

1. Reconnaissance. The general site is decided by a careful study of existing small-scale maps and a thorough study of the actual ground, augmented by rough surveys.

2. Preliminary survey. A survey is made of the chosen site. This survey covers the watersheds, possible reservoir sites, dam sites, and sites for the buildings. It is called a **preliminary survey** and consists of determining the relative positions of existing topographic features and existing construction. Any survey which measures that which already

exists is called a preliminary survey. The preliminary survey includes **control surveys** and **topographical surveys.**

2*a*. **Control survey** (see Fig. 12). A relatively few points called stations are permanently marked by monuments. They are arranged so that they can be easily surveyed, and their horizontal positions are determined by relatively precise triangulation and traverse. The elevations of the same or other permanent points called bench marks are determined by relatively precise leveling. These positions and elevations provide an accurate framework upon which less accurate surveys can be based,

FIG. 13.—A cloth tape. These tapes contain metal threads to reduce stretching. They are also known as metallic tapes. (*Keuffel & Esser Co.*)

without the accumulation of accidental errors or the high cost of making all measurements precise.

2*b*. **Topographic survey.** By using cloth tapes (metallic tapes) (see Fig. 13), hand levels, plane tables, stadia, or photogrammetry, the topographic features are connected to the control surveys by comparatively low-precision measurements.

3. **Map.** Maps and profiles are drawn, giving all the required data.

4. **Design or plan.** By use of the map data, the construction plans are completed, and upon them are stated **location dimensions** to be measured from topographic features or control points. Vertical heights are usually given by elevations. Horizontal positions are given in the best practice by coordinates (see Fig. 14).

5. Location survey. The plans are executed first by marking on the ground the positions of the construction planned, according to the location dimensions. This is called **staking out.** It is accomplished by measuring from the control points or topographic features. This is the reverse process of the preliminary survey, requires different techniques, and is called a **location survey.**

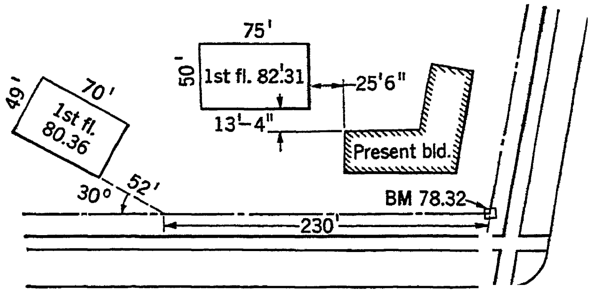


FIG. 14.—Typical location dimensions found on plans.

The techniques used in a location survey are the same as those used in aligning master jigs and assembly jigs and in positioning large or heavy parts. In both cases the problem is to establish position, size, and shape according to an existing plan.

PROBLEMS

1. Express the following directions by two other means:

a. N 20°10′ E	*e.* A_s 90°50′	*i.* A_n 310°50′
b. A_n 130°40′	*f.* S 20°30′ E	*j.* A_s 210°20′
c. A_s 320°20′	*g.* A_n 30°10′	*k.* S 40°10′ W
d. N 10°30′ W	*h.* A_s 40°20′	*l.* A_n 250°40′

2. Compute the opposite, or back, directions for the values in Prob. 1.
3. Express the rule for computing back directions for (*a*) azimuths, (*b*) bearings.
4. Express the following vertical angles by zenith distances:
   a. 20°10′
   b. −6°20′
   c. 60°40′
   d. −7°10′

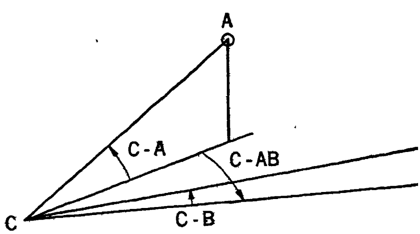


FIG. 15.—Illustration for Probs. 5–10.

5–10. Assume that the instrument center is at C. Find the difference in elevation, the horizontal length, and the slope length between A and B for the six sets of data given. Compute to the nearest foot only (see Fig. 15).

	5	6	7	8	9	10
Horizontal angle C-AB	20°	30°	40°	10°	25°	35°
Horizontal length C-A	100′	200′	200′	100′	60′	40′
Horizontal length C-B	200′	100′	200′	100′	20′	30′
Vertical angle C-A	20°	10°	10°	15°	−5°	8°
Vertical angle C-B	30°	−10°	20°	−5°	10°	−4°

11. Indicate by A, S, or B whether the following produce accidental errors, systematic errors, or blunders:

a. Swinging plumb bob.
b. Reading 9 for 6.
c. Repaired tape.
d. No reading glass for transit.
e. Using the wrong clamps.
f. Poor light.
g. Recopying field data.
h. Uncorrected slope measurements.
i. Transit not level.
j. Failure to focus.

12. Determine the accuracies of the following surveys, and name the order of accuracy:

	Error in measurement	Distance measured, ft
a	10′	22,361
b	0.05′	3,005
c	1.27′	14,000
d	0.09′	1,002
e	1.00′	25,000
f	0.84′	8,400

Determine the orders of accuracy of the following level surveys:

	Error, feet	Distance, miles
g	0.027	10
h	0.035	2
i	0.016	1
j	0.016	0.5
k	0.117	8
l	0.164	2

CHAPTER III

HORIZONTAL MEASUREMENT

39. Steel Tapes. Except for determinations of low precision, horizontal lengths are measured by steel tapes. In use they are supported either throughout their entire length or at regular intervals (Figs. 1, 2).

40. Whenever possible a spring balance handle should be attached to the forward end of the tape. A spring balance handle indicates the value of the pull applied. This ensures an accurate pull and speeds up the work

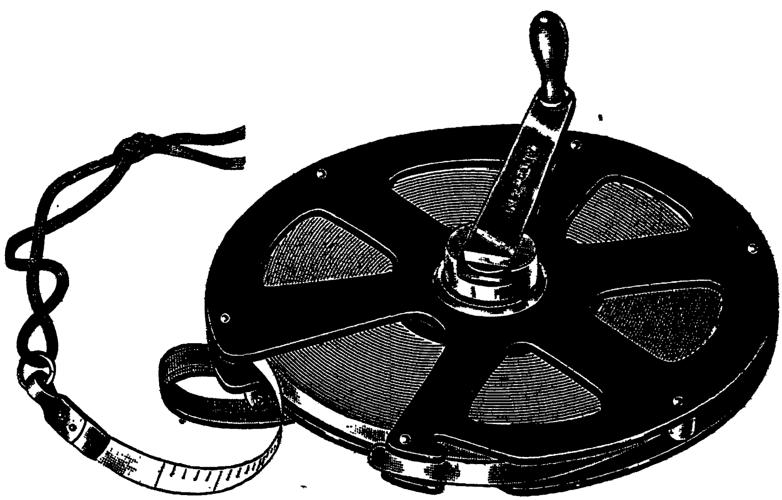


FIG. 1.—A Keuffel & Esser Wyteface steel tape in a convenient reel. (*Keuffel & Esser Co.*)

by steadying the pull. When the accuracy required is greater than 1:3,000, a thermometer must be used to measure the tape temperature. This is attached to the tape near one end with adhesive tape. The bulb should be in contact with the steel (Fig. 3).

41. Corrections to Field Measurements. Three corrections are applied to field measurements, **tape correction, temperature correction,** and **slope correction.**

42. Tape Correction. A tape must be compared with a standard to determine its actual length. The U.S. Bureau of Standards is equipped to compare a tape with the international meter, which is now accepted

as the standard of length for the United States. Tapes standardized by the Bureau of Standards are often kept in the office and used as standards for field tapes (Fig. 4).

43. Since the length of a tape is affected by the temperature, the tension applied, and the type of support, a tape should be standardized at the

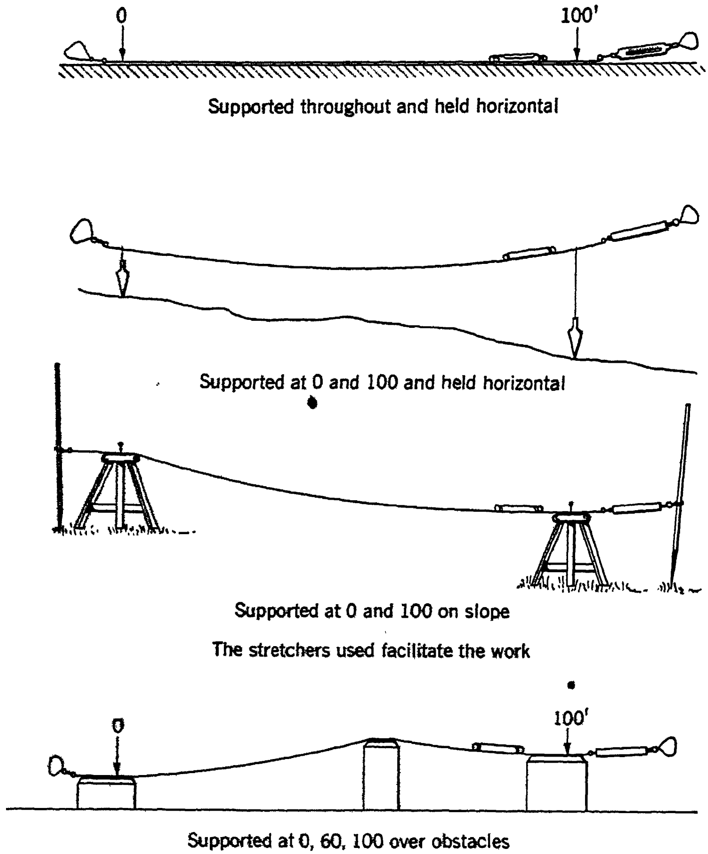


FIG. 2.—Methods of supporting a tape.

standard temperature of ~~68°F~~ and with the same tension and type of support that will be used in the field.

44. A tape correction is that quantity which must be added to the **nominal** length of a tape to obtain the **actual** length of the tape (at 68°F).

45. Thus a tape that is too short has a **minus** tape correction. Also, the value of a measurement determined with a tape that is too short must have a correction **subtracted** from it.

46. For example, assume that a tape nominally 100 feet long is found to be 99.98 feet at 68°F when standardized. The tape correction is then −0.02 feet. A length found to be 300 feet with that tape is actually 299.94 feet.

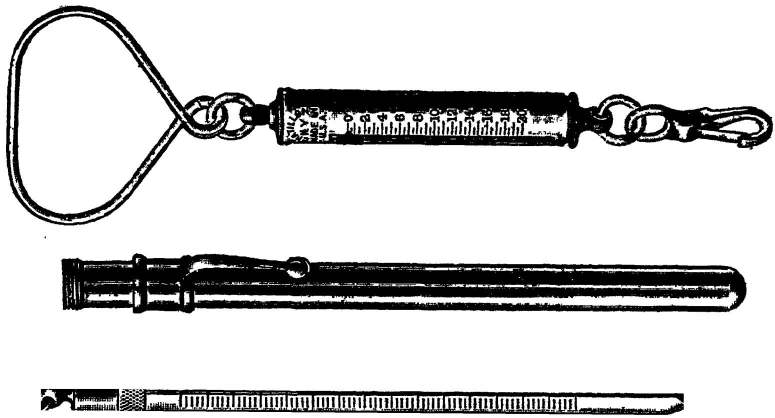


FIG. 3.—A spring balance handle and a tape thermometer. (*Keuffel & Esser Co.*)

47. In applying a tape correction, either to the tape itself or to a distance measured with the tape, the rule is: "Subtract when the tape is too short; add when the tape is too long."

48. Temperature Correction. The coefficient of expansion of steel is usually taken at 0.00000645 per degree Fahrenheit. This amounts to

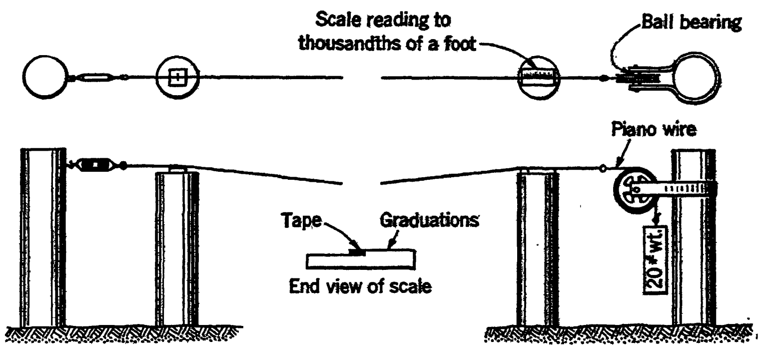


FIG. 4.—Base for comparing tapes.

about 0.01 foot per 100 feet per 15°F. It is to be remembered that the tape is standardized at 68°F.

49. For example, assume that a tape has a correct length at 68°F, i.e., no tape correction. If a measurement, made at 53°F, was recorded as 300 feet, the tempera-

ture correction would be

$$C_f = 300 \text{ ft} \times 0.00000645 \times 15 = 0.029 \text{ ft}$$

or

$$C_f = 3 \times 0.01 \text{ ft} \times {}^{15}\!/_{15} = 0.03 \text{ ft}$$

50. The correction is subtracted as the tape would be too short. Hence the actual length would be 299.971 feet.

51. Slope Correction (See Fig. 5). Often a measurement is made on a slope and reduced to the horizontal by computation. When the slope is measured in angular units, the correction is given as follows:

$$C_h = L \text{ vers } \alpha$$

where L = length recorded
α = angle of slope
(NOTE: versine = 1 − cosine; tables are available.)

52. When the difference in elevation of two ends of a measurement is known, the correction is computed as follows:

$$C_h = \frac{h^2}{2L}$$

where h = difference in height of the two ends
L = length recorded

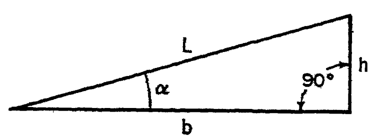


FIG. 5.—Slope correction.

NOTE: From Fig. 5,

$$L^2 - b^2 = h^2$$
$$(L - b)(L + b) = h^2$$
$$L - b = \frac{h^2}{L + b}$$

But

$$L - b = C_h$$
$$L + b = 2L \text{ (very nearly)}$$

By substitution,

$$C_h = \frac{h^2}{2L}$$

53. Slope corrections are always subtracted, as the tape is made too short by the slope.

54. Combining Several Corrections. Strictly speaking, corrections should be combined by successive multiplication. Assume that for a given length the following unit corrections have been computed and were to be applied:

$$\begin{aligned}\textbf{Unit}\text{ tape correction} &= a\\ \textbf{Unit}\text{ temp. correction} &= b\\ \textbf{Unit}\text{ slope correction} &= c\end{aligned}$$

Let

$$\begin{aligned}D &= \text{true distance}\\ L &= \text{length recorded}\end{aligned}$$

Then

$$\begin{aligned}D &= L(1 + a)(1 + b)(1 + c)\\ &= L(1 + a + b + c + ab + ac + bc + abc)\end{aligned}$$

But the values of a, b, and c are very small so that products of any two are negligible. Eliminating such products,

$$\begin{aligned}D &= L(1 + a + b + c)\\ &= L + La + Lb + Lc\end{aligned}$$

Thus each of the corrections can be based on the length recorded and combined by addition.

55. For example, a length of 200 feet was measured at 38°F with a 100-foot tape actually 99.97 feet long at 68°F. The total slope correction was 0.07; then,

$$\begin{aligned}L &= 200\\ a &= -\frac{0.03}{100}\\ b &= -\left(\frac{68-38}{15}\right)\frac{0.01}{100} = -\frac{0.02}{100}\\ c &= -\frac{0.07}{200}\\ D &= 200 - 0.06 - 0.04 - 0.07 = 199.83\end{aligned}$$

56. In practice, the computations are made in a slightly different way. The following example represents the conventional form of computation.

57. Example. Assume the measurement had been made as shown in Fig. 6. The notes and computations would be as follows:

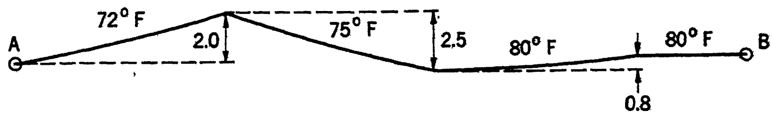


FIG. 6.—Example of field measurement.

Length *A-B*. Tape 99.982.

Dist.	Temp.	h	Slope cor.	
100	72	2.0	$\frac{4.0}{200}$	0.020
100	75	2.5	$\frac{6.25}{200}$	0.031
100	80	0.8	$\frac{.64}{200}$	0.003
52.71	80	0	0	0
352.71	Aver. 76			0.054
	−68			
	8			

Tape cor. = 3.53 × 0.018 = −0.064
Temp. cor. = 353 × 0.00000645 × 8 = +0.018
Slope cor. = −0.054
Total cor. = sum = −0.100

Recorded length.. 352.71
Correction.. −0.100
Final length.. 352.61

58. Changes in Tape Correction. Sometimes a tape is used in the field under conditions other than when standardized, i.e., with different tensions and different types of support. When this occurs, it is necessary to change the tape correction for the new **tension** and the new **sag.**

59. Tension. When the tension is increased, the tape stretches. The increase in length is expressed as follows:

$$C_p = \frac{L(t - t_0)}{30{,}000{,}000S}$$

where C_p = increase in length, ft (a negative result indicates a decrease in length)

L = length of tape, ft

t = tension, lb, applied in the field

t_0 = tension, lb, applied when standardized

S = cross-sectional area, sq in.

60. Sag. Of course, when a tape is supported at several points, it sags between the supports. The sag causes the ends of the tape to move together. The following formula expresses the amount the ends of the tape are brought together by this sag effect only. The tape is assumed to remain the same physical length, no matter what the tension may be.

$$C_s = \frac{w^2 l^3}{24 t^2}$$

where C_s = shortening between one pair of supports, ft
w = weight of the tape, lb per ft of tape
l = distance between the pair of supports, ft
t = tension, lb

61. When the values of the effect of different types of support are computed, they are added algebraically to the tape correction determined by the standardization of the tape and thereafter the new tape correction is used in the usual way.

62. Example. Assume that the length of the tape by standardization is 100.010 feet and that it was standardized at 68°F when supported at 0- and 100-foot marks under a tension of 20 pounds. The tape correction therefore is +0.010.

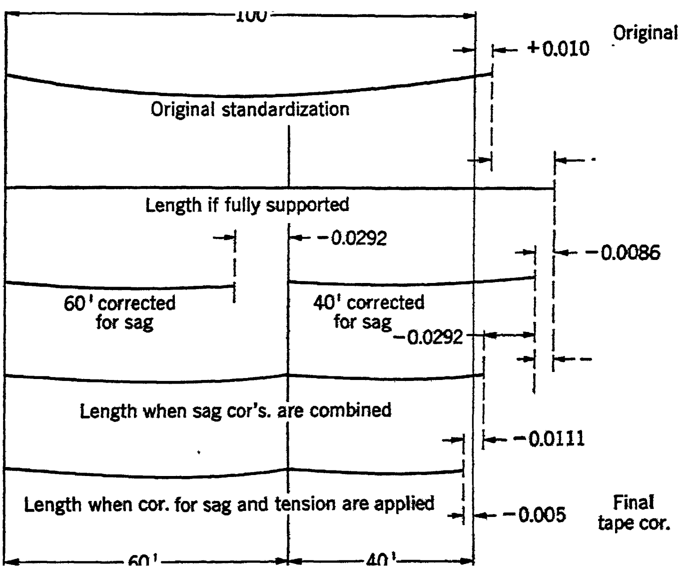


FIG. 7.—Steps in computing a new tape correction.

What will be the tape correction when supported at the 0-, 60-, and 100-foot points and at a tension of 10 pounds?

Assume the following values:

Cross-sectional area	0.003 sq. in
Weight	0.018 lb per ft

First find the increase in the length of the tape correction if the tape had been fully supported when standardized, other conditions being the same. This would mean adding the sag correction for 100 feet. Then subtract the sag correction for

60 feet and also for 40 feet. Finally, subtract the decrease in length due to the decrease in tension (see Fig. 7). Thus,

When standardized,

$$C_s = \frac{(0.018)^2(100)^3}{24(20)^2} = 0.0338 \text{ ft}$$

When used (60-ft section),

$$C_s = \frac{(0.018)^2(60)^3}{24(10)^2} = 0.0292 \text{ ft}$$

When used (40-ft section),

$$C_s = \frac{(0.018)^2(40)^3}{24(10)^2} = 0.0086 \text{ ft}$$

Change in tension

$$C_p = \frac{100(10 - 20)}{30{,}000{,}000(0.003)} = -0.0111 \text{ ft}$$

Collecting,

	Ft
Tape cor. when standardized	+0.010
Sag cor. to fully supported	+0.0338
Sag cor. for 60-ft span	−0.0292
Sag cor. for 40-ft span	−0.0086
Tension cor	−0.0111
New tape cor. = sum	−0.005

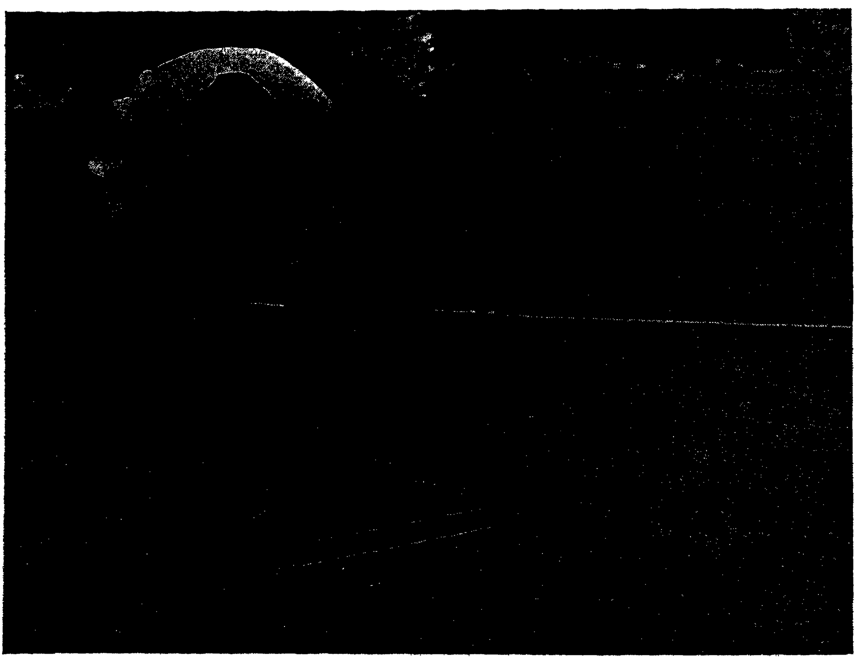


FIG. 8.—Precise taping, applying tension.

63. Taping Procedure. There are many standard procedures for taping, depending on the accuracy desired and the quantity of the work. In large projects, speed becomes a very important item.

64. Precise Taping. Accuracies of better than 1:3,000 can be obtained only when the tape is supported throughout or held on permanent or semipermanent supports which are placed at known intervals and the elevations of which are determined by leveling. The tension must be controlled by a spring-balance handle and the tape temperatures are measured with a thermometer so that proper corrections can be applied. Intermediate points should preferably be aligned with a transit. Fine

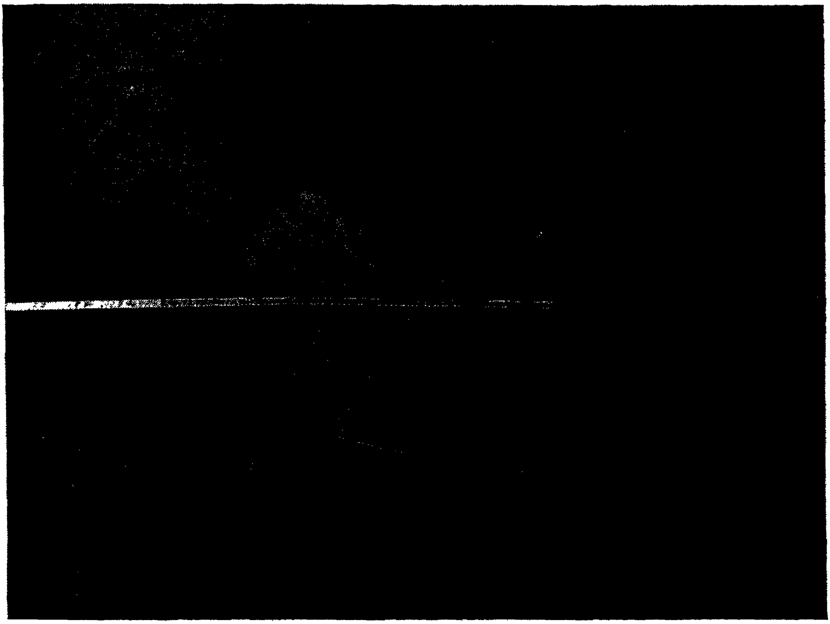


FIG. 9.—Precise taping, "head contact."

marks must be used to show the positions of the end of the tape. When speed is not essential as is the case for the type of work covered in this text, any method that conforms with the above will be successful. The tape can be supported on a floor, a street pavement, wooden stools, or other objects. Ordinary pins or fine pencil marks can be used to mark the intermediate points. If the surface will not take a pencil, adhesive tape should first be laid down (see Figs. 8, 9, 10).

65. Typical Taping. Most taping required must have an accuracy of 1:2,000 to 1:3,000 and must be accomplished over obstacles or rough ground. It is so frequently used that it is here described in detail.

There are basically two procedures, the measurement of a distance between two existing points and the setting of stakes and tacks in the proper positions for construction. The first type is covered in this chapter and the second type in a later chapter.

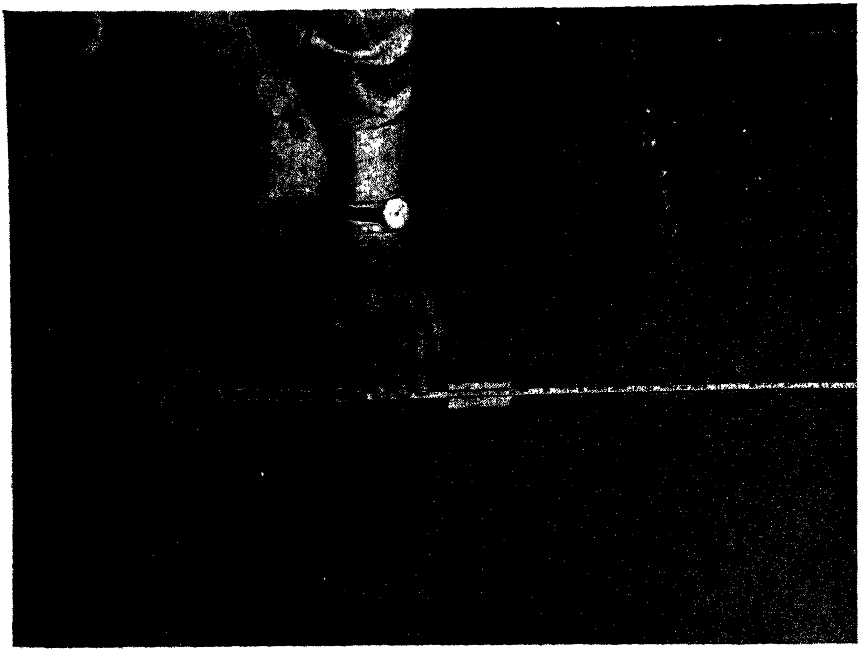


FIG. 10.—Precise taping, using a mark on adhesive tape.

66. Procedure for the Usual Method of Taping.[1] Usually a 100-foot tape, graduated to hundredths of a foot, should be used. The inch is not generally used in surveying, for it introduces difficulties in computations and increases the opportunity for blunders. In jig alignment and the like, when dimensions are given in inches, special tapes and rules reading in inches and fractional or decimal parts of the inch are used. If available, a spring balance should always be attached to the forward end of the tape. In the following description a distance is to be measured from *A*

FIG. 11.—A range pole.

to *B*. The zero mark on the tape is kept to the rear, although some engineers prefer to keep the tape reversed. The position of the hands, etc., mentioned refers to right-handed persons.

67. A signal, usually a range pole (see Fig. 11), is set at Station *B*. The head tapeman unreels the tape by walking toward *B* while the rear tapeman holds the zero end at *A*. When the head tapeman reaches the end of the tape, he removes the

[1] See also Arts. 228–232.

reel and attaches a handle at the end of the tape. The rear tapeman, sighting the signal at B, directs him by voice until the head end of the tape is on line. He should name the direction and estimated length of movement, thus, "west, two-tenths," etc. The head tapeman pulls the tape straight and makes a rough measurement while the rear tapeman checks the alignment. The rear tapeman should keep his eyes above the mark and the head tapeman should keep on one side of the tape so that the rear tapeman can see the target at B during this process. An error of 6 inches in alignment will not affect the results, and therefore subsequent to this rough measurement no further attention is given to alignment. The head tapeman prepares a place to mark the distance where the rough measurement fell. In grass, he rubs a small spot

FIG. 12.—Keel, often called lumber crayon. (*Keuffel & Esser Co.*)

clear of vegetation; on a pavement, he may mark a small spot with **yellow keel** (see Fig. 12).

68. The men then adjust the lengths of the plumb-bob cords so that the bobs will just swing clear when the tape is in position. The tape should be horizontal in the judgment of the head tapeman and should be as near the ground as possible. If accuracy is desired, it should hang free of all support. With the handles of the tape in their right hands, the men should face the tape (their left sides toward each other). The plumb-bob cord is held on the far side of the tape bent over the tape and held on the proper graduation with the thumb of the left hand (Fig. 13). In measuring,

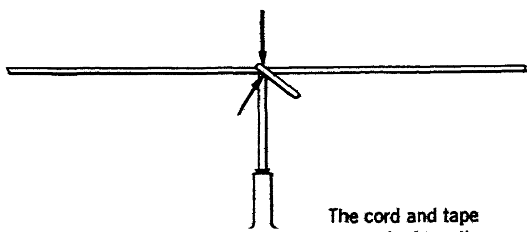


FIG. 13.—Holding the plumb-bob string on the tape.

the tape is moved up and down slightly, tapping the point of the bob on the mark to dampen the swing. The stance must be steady. When the tape is high, the feet should be planted well apart along the line of the tape; when the tape is low, one knee must be placed on the ground.

69. The head tapeman applies the tension gradually, estimating the correct pull. When the tape becomes steady and his bob still, he lowers the tape so that the bob rests on its point. If the ground is soft, the hole the point makes is sufficient for the moment. He releases the tape and places a tack in the hole. Usually a **chain pin** (see Fig. 15) is placed in the ground near the tack so that the rodman can find the

tack and also so that it may act as a tally. If he is working on a pavement or other hard surface, the head tapeman holds the bob nearly upright and thus the point remains where it marks the correct position. He accomplishes this by regulating the cord in his left hand. He then releases the tape, reaches the bob with his right

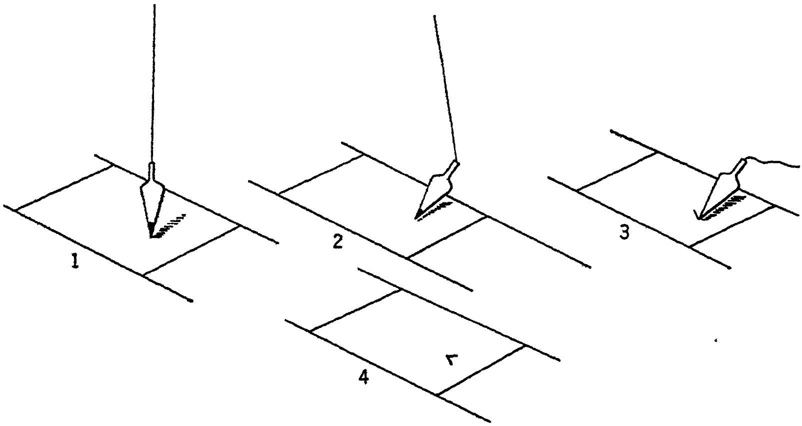


FIG. 14.—Steps in making a mark on masonry.

hand, and marks the position of the point (Fig. 14). Usually he does this by making a scratch with the point from the position it occupies. The beginning of the scratch is the mark. He makes a second scratch from the point, at right angles to the first, forming a V. He marks the number of tape lengths (stations) on the pavement with keel. The rear tapeman calls the number of the station **he occupies,** and the head tapeman calls the number **he is marking.**

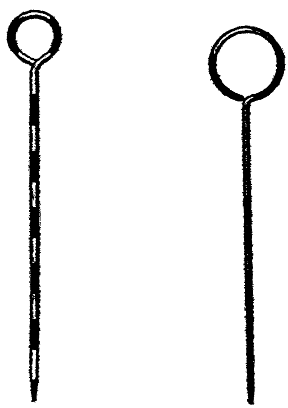


FIG. 15.—Chain pins, often called chaining arrows. (*Keuffel & Esser Co.*)

70. Frequently the measurement is repeated for a check after it is marked if either man believes this to be desirable.

71. The head tapeman moves forward toward *B*, dragging the tape. The rear tapeman recovers the chain pin. When the zero mark comes to the station, the rear tapeman calls "chain" or the number of the station. The head tapeman stops and can usually line himself in within a foot or so by looking back along the line. The procedure for measurement is then repeated.

72. Upon reaching *B* the head tapeman either reels in part of the tape or walks on past *B* carrying the head end forward. He returns to *B* to make the measurement. While plumbing as previously described, he slides the plumb-bob cord along the tape until the bob is on the mark; then, holding the cord in position on the tape, he reads the graduations to himself. The rear tapeman comes forward and reads the graduations out loud. If the readings agree, they are recorded. The number of tape lengths is checked by the chain pins or the number marked on the last station.

73. Breaking Tape. When at any time the slope is so great that the entire tape cannot be used, a process called **breaking tape** is employed. After carrying the tape out to the full distance the head tapeman returns to the point where the tape can be held level. He selects a certain foot mark, which he announces to the rear tapeman. When the mark is set at this distance, the rear tapeman comes forward, taking the tape from the head tapeman so that there is no opportunity of using the wrong tape graduation, and then uses this graduation as though it were zero. No chain pin is set. Sometimes the **plus** (distance from the last station) is marked on the pavement (Fig. 16).

74. Other Methods of Taping, by Use of Plumb Bobs. Stakes are used in taping over soft ground, particularly when measurements for topography are to be made from them later. When stakes are set, the head tapeman must obtain a more precise measurement at first. Usually both men use plumb bobs even for the first rough measurement. The head tapeman allows the bob to drop so that it stands in the position where the stake is to be set. The stake is then driven, and the tape is

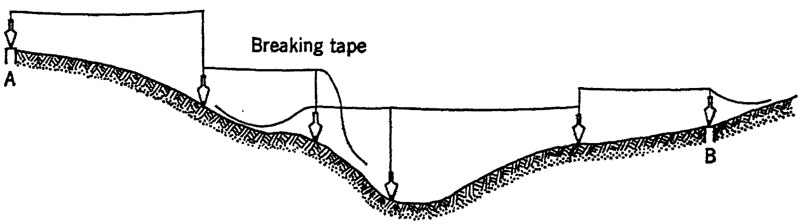


FIG. 16.—Operations in taping.

used again to find the exact position on the stake. To mark the point on the stake the bob is forced into it so that the point makes a hole. A tack is driven in the hole.

75. The stations are aligned with a transit when precise measurements are later to be made from them.

76. The Accuracy Obtained with Plumb Bobs. Even experienced tapeman have difficulty in preventing the tape and the bobs from moving during measuring. The error from this source is between 1:5,000 and 1:10,000. Variations in tension of 5 pounds introduce an error of 1:10,000 with a tape of average cross section 100 feet long supported at the ends. Temperature may introduce an error up to 1:5,000, so that all in all this type of measurement has an accuracy seldom better than 1:2,500. Using spring-balance handles will improve the accuracy to 1:3,000; with temperature correction as well, an accuracy of 1:5,000 can be reached.

77. The great advantage in this type of taping is that the tape is held level. The effect of slope increases nearly as the square of the difference in elevation of the ends; thus, when the tape is nearly level, the error can be disregarded. This eliminates the necessity of measuring the slope.

PROBLEMS

Find the corrected length from the following field notes:

	Tape length by standardization	Dist.	Temp., °F	h
1	Tape 99.998	100	40	2.0
		100	41	3.0
		52.68	41	0
2	Tape 99.964	100	95	1.5
		100	96	0.7
		75.62	97	0
3	Tape 100.027	100	37	3.0
		100	38	3 2
		14.61	38	0
4	Tape 100.008	100	62	2.0
		100	62	2.1
		100	62	2.2
		100	62	0.8
		10.74	62	0
5	Tape 99.981	100	87	0.8
		100	87	0.7
		100	86	1.1
		46.71	85	0
6	Tape 99.997	100	47	3.0
		100	48	1.0
		100	49	2.0
		58.83	48	0
7	Tape 99.990	100	35	4.2
		100	36	0
		100	37	2.5
		100	36	5.0
		14.20	36	0

	Tape length by standardization	Dist.	Temp., °F	Slope
8	Tape 99.961	100	90	3°00′
		100	91	1 15
		100	89	1 55
		22.10	90	0
9	Tape 100.005	100	45	2 00
		100	42	2 10
		100	41	1 15
		100	40	0 10
		41.06	42	0

Find the tape length to be used for correcting field data when the following conditions existed:

	Conditions when standardized					Conditions when used	
	Std. length	S	w	t_0	Support used	t	Support used
10	99.998	0.003	0.018	20	0–100	10	Supported throughout
11	100.027	0.0025	0.015	10	Throughout	20	0–50–100
12	100.008	0.003	0.018	15	0–100	10	0–50–100
13	99.980	0.004	0.024	12	Throughout	22	0–100
14	100.016	0.002	0.012	8	Throughout	15	0–100

CHAPTER IV

THE TRANSIT

78. The Transit. The transit is, of course, the key instrument in surveying. With its aid great structures and small machines are laid out. The accuracy it produces results from careful manufacture, good design, and the important fact that it can be so operated that it automatically eliminates any residual errors in its construction or its adjustment. The principle upon which this depends is the principle of **reversal.** It is introduced in the transit by mounting the telescope on the horizontal axis so that it will **transit,** and thus can be used both in its normal position called **direct** and in its inverted position called **reversed,** and by mounting the levels on a part that turns about the vertical axis.

79. To be able to recognize when the transit can and should be used and to obtain good accuracy in its use, it is necessary to know how it is constructed and particularly to understand the geometric principles involved in its design.

80. Transits are designed for a number of specific purposes. The type described in this text is a repeating instrument equipped with a vertical circle and telescope level. It is often called an **engineer's transit** and is the most useful instrument for the type of work covered in this text. Figure 1 shows the construction of a typical engineer's transit.

81. (See Fig. 2.) The transit consists of three parts, the alidade at the top, the horizontal circle in the center, and the leveling head at the base. The alidade includes the entire upper part of the instrument, i.e., the telescope, the standards, the verniers, the plate levels, and the inner spindle (inner center). The horizontal circle includes the outer spindle (repeating center). The leveling head includes the leveling screws, the bearing for the outer spindle, and the threads that screw on the tripod. The alidade and the horizontal circle can turn independently in a horizontal plane around the vertical axis.

82. The three parts are operated by two clamps, each equipped with a slow motion. The upper clamp clamps the circle to the alidade, and the lower clamp clamps the circle to the leveling head. When a clamp has been tightened, the appropriate slow motion can be used to make a fine setting.

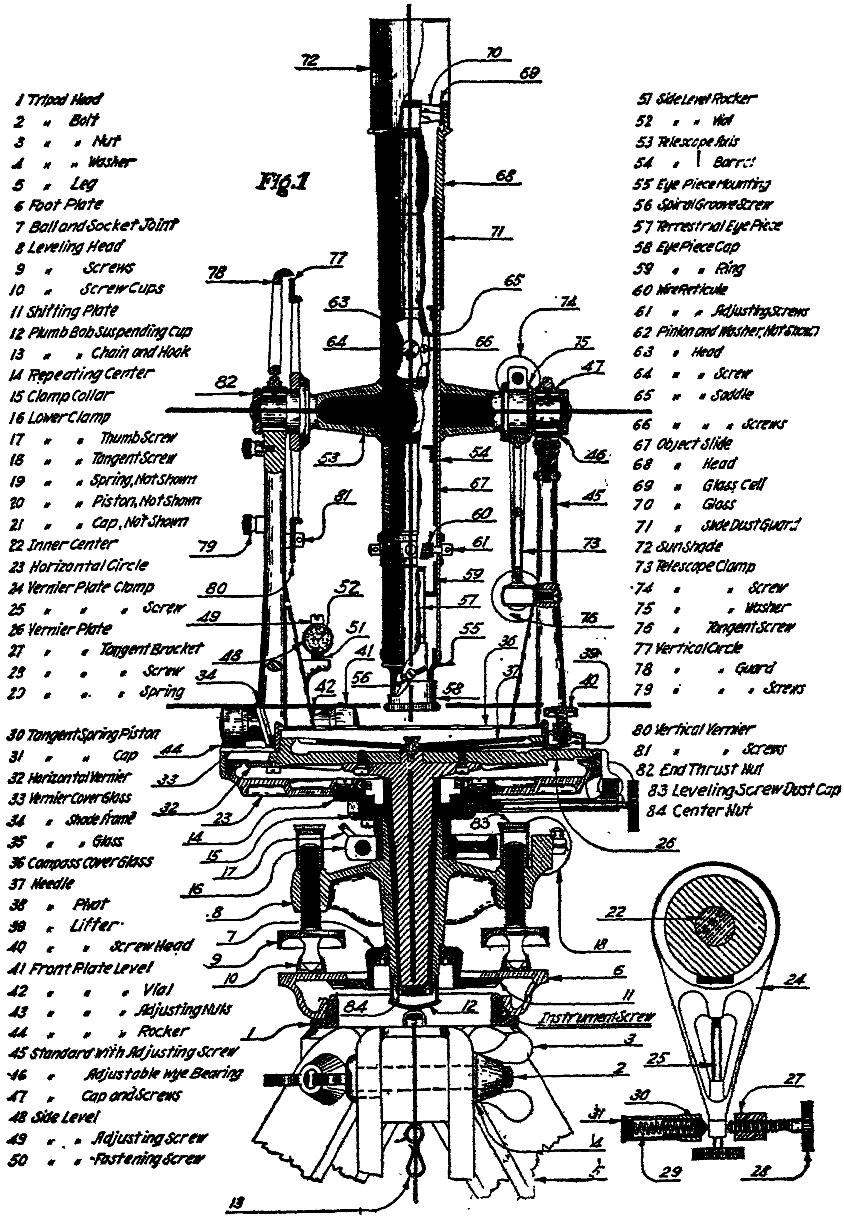


FIG. 1.—Cross section of a transit showing the nomenclature of the various parts and the chief geometric lines that must be properly related. (*C. L. Berger & Sons, Inc.*)

FIG. 2.—The three parts of a transit: alidade, circle, and leveling head. (*Keuffel Esser Co.*)

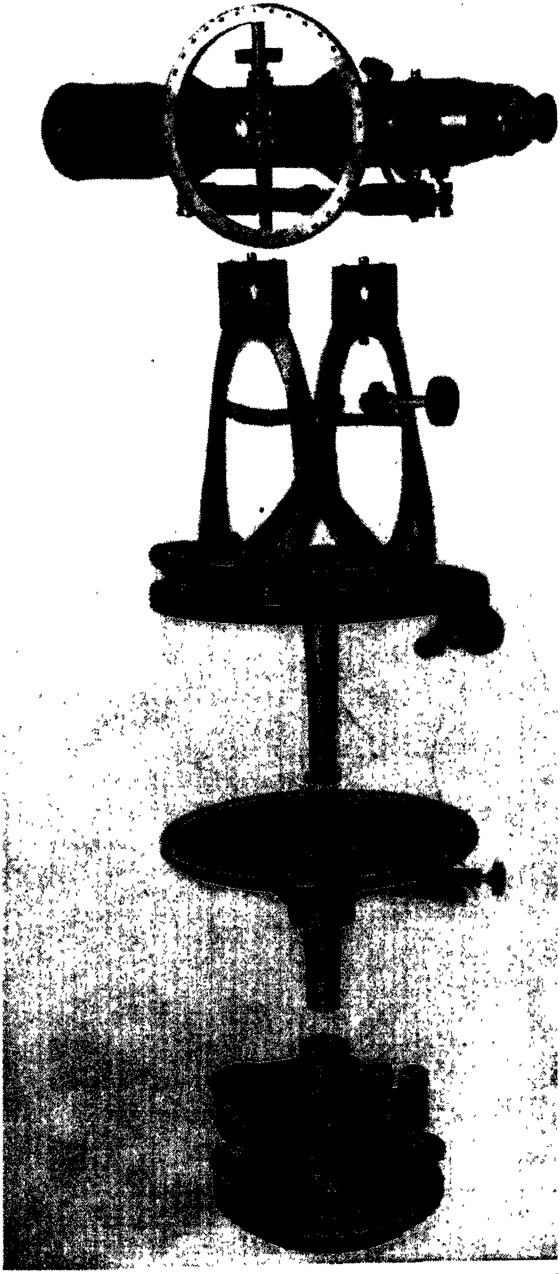


FIG. 3.—A Gurley transit taken apart. (*W. & L. E. Gurley.*)

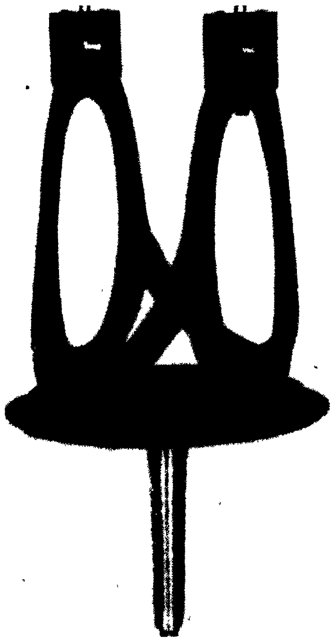


FIG. 4.—A Gurley standard. (*W. & L. E. Gurley.*)

83. The arrangement of the clamps and slow motions makes it possible to measure a horizontal angle as follows:

By using the upper clamp and slow motion, the zero of the vernier is set precisely opposite the zero on the graduated circle. Then, by using the lower clamp and slow motion, the telescope is pointed at a target or signal marking one side of the angle. The zero setting is, of course, undis-

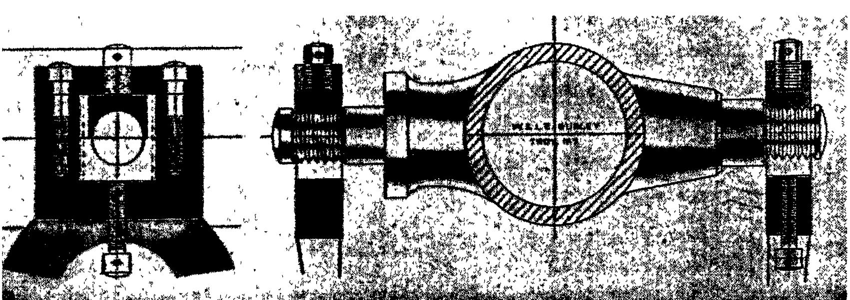


FIG. 5.—The Gurley type of horizontal axis bearings. (*W. & L. E. Gurley.*)

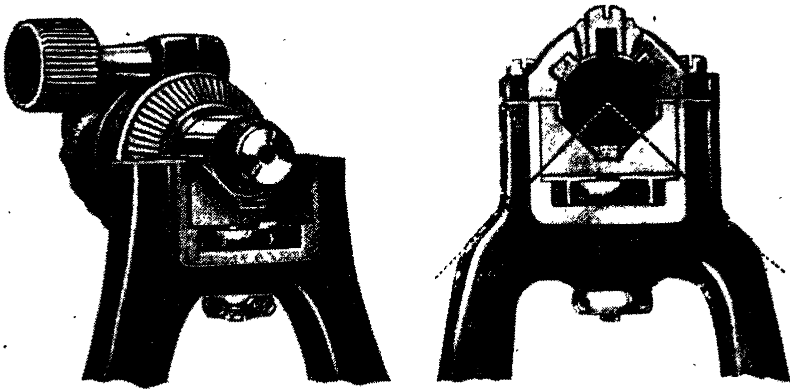


FIG. 6.—The type of bearing for the horizontal axis used by C. L. Berger & Sons. (*C. L. Berger & Sons, Inc.*)

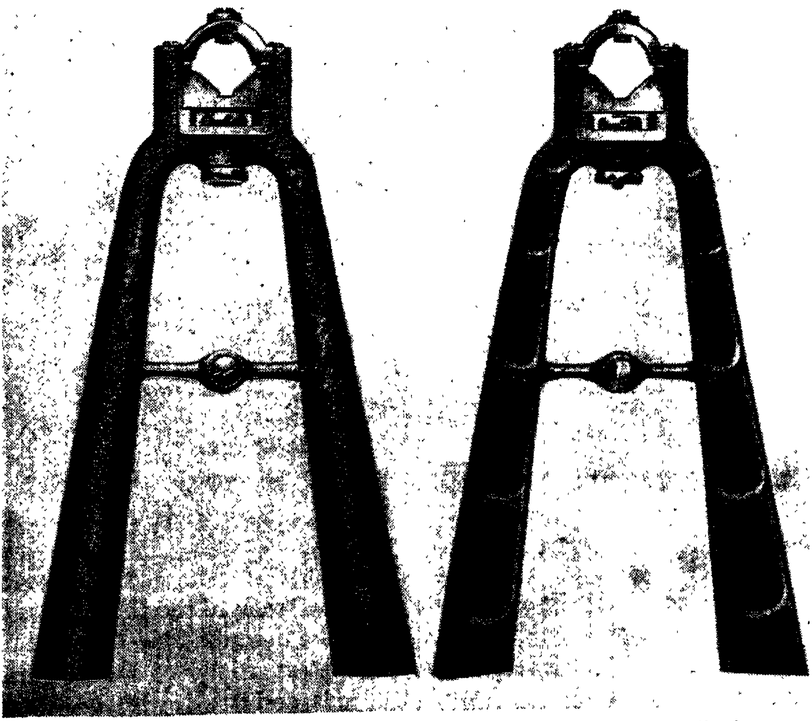


FIG. 7.—Typical transit standards. (*C. L. Berger & Sons, Inc.*)

turbed by this process. By using the upper clamp and slow motion, the telescope is pointed at the second signal. The circle remains stationary during this process while the vernier travels around the circle. When the pointing is complete, the position of the vernier on the circle gives the value of the angle.

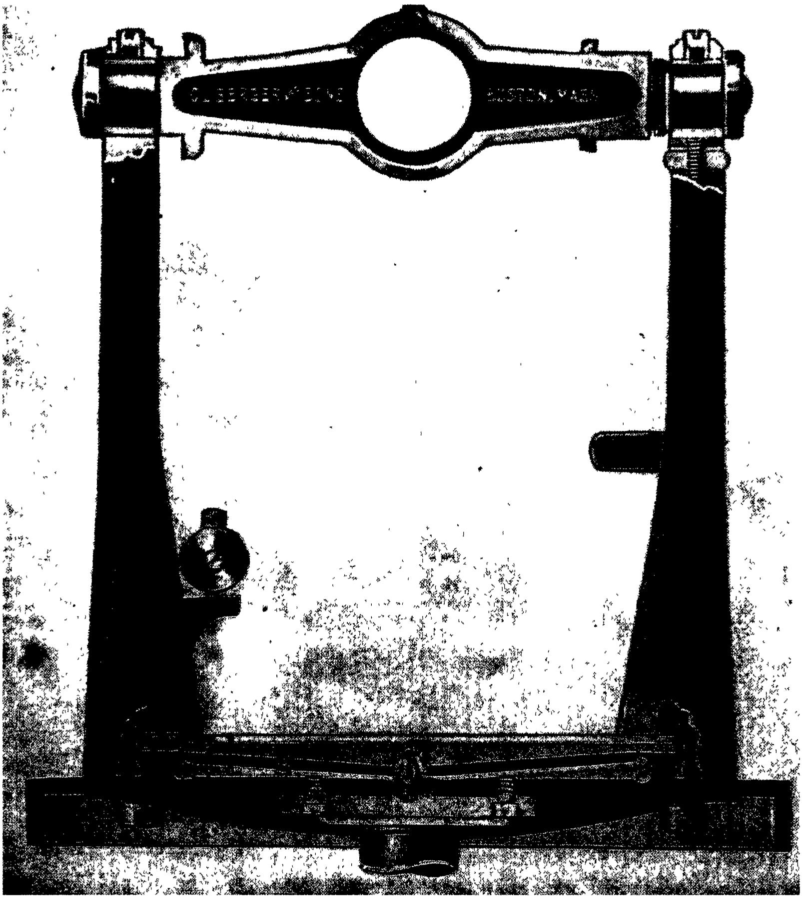


FIG. 8.—A vertical cross section through the alidade. (*C. L. Berger & Sons, Inc.*)

84. It is clear that the essential elements of each of the three parts of the transit are of great importance. They are described below in detail.

85. The Alidade. The alidade consists essentially of a **telescopic sight,** which is mounted on the horizontal axis, and two **double verniers,** called A and B respectively which together act as an index showing the

horizontal direction of the alidade according to the graduations of the horizontal circle. The two **plate levels** are mounted on the alidade.

86. The Telescopic Sight (See Fig. 9). The telescopic sight consists of the following: (1) A pair of cross hairs mounted in a ring or reticle near the rear of the telescope tube. (2) A microscope, or eyepiece, which magnifies the cross hairs and must be focused on them according to the eyesight of the observer. (3) An object glass, or objective lens, which

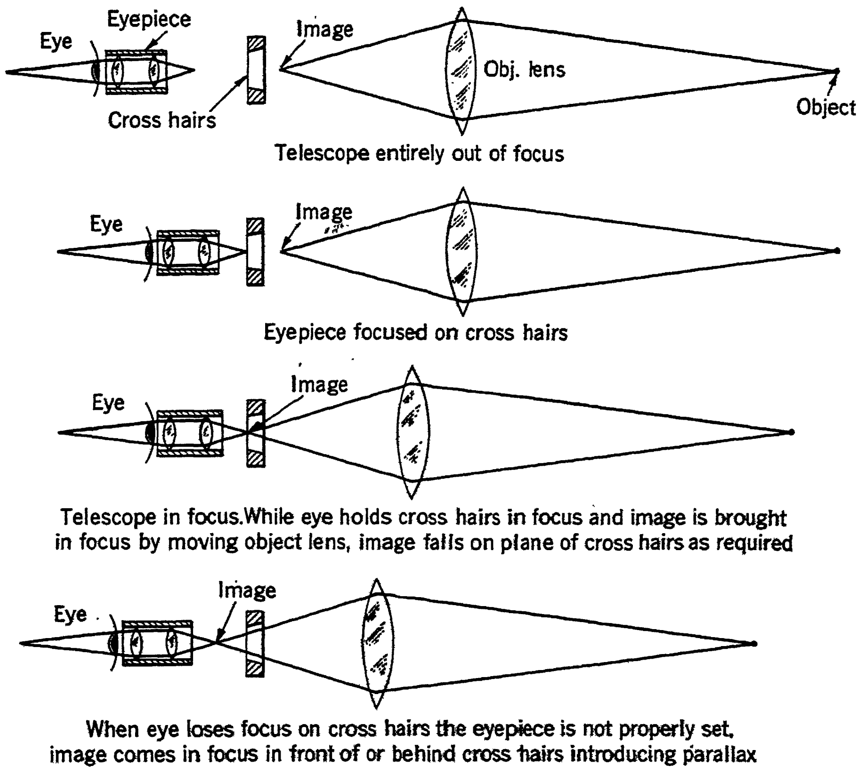


FIG. 9.—Diagrammatic view of telescopic sight in use.

forms an image within the telescope. The image is found at a distance behind the lens that varies with the distance from the lens to the object sighted, as the object and its image are at conjugate foci. The observer observes the cross hairs through the eyepiece and moves the lens backward and forward until the image is clear. This can occur only when the image is on the plane of the cross hairs. Under these conditions the cross hairs become part of the image, and to the observer they appear superimposed on the object toward which the telescope is pointed. If

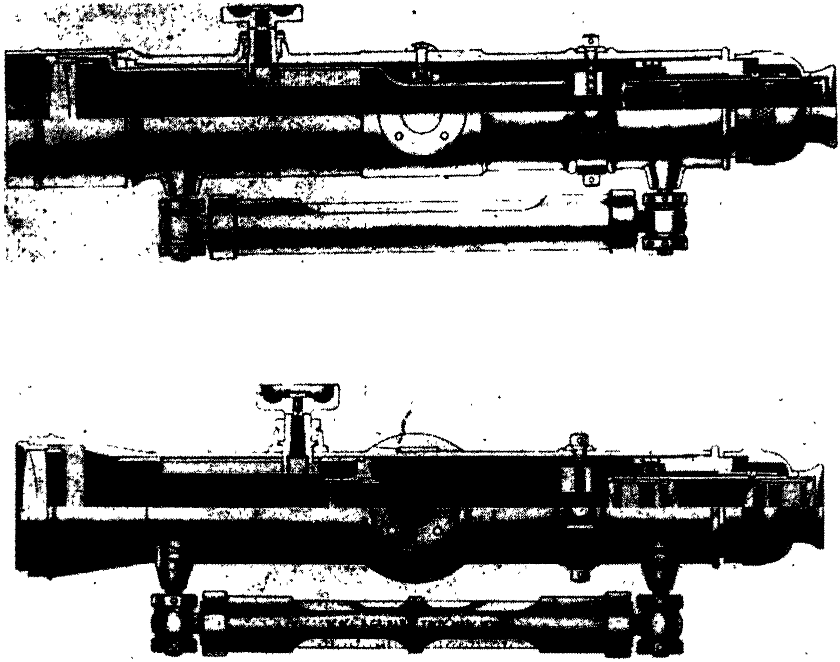


FIG. 10.—Quarter sections of external and internal focusing systems as used in Gurley instruments. The upper picture is the external system. (*W. & L. E. Gurley.*)

the observer allows himself to look at the image instead of the cross hairs, it is possible to change the focus of the eye so that the image is seen clearly a short distance in front of or behind the cross hairs. The cross hairs will then appear to be nearly as sharp as before. When the image is not at the same distance from the observer as the cross hairs, the cross

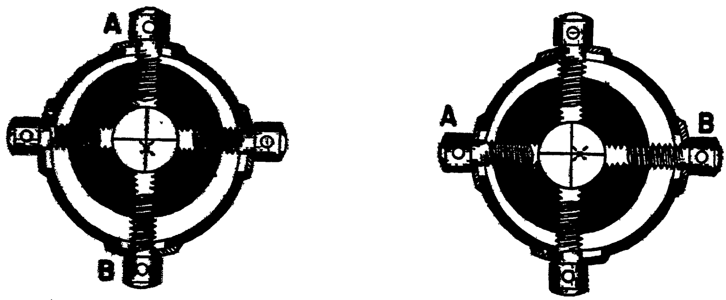
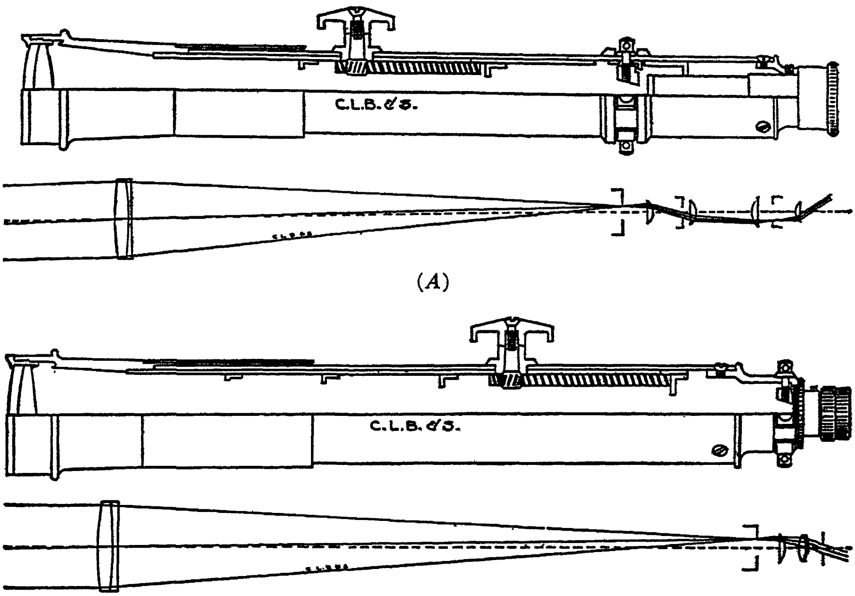


FIG. 11.—A cross section of a transit showing the cross-hair reticle mounting and the means of adjustment. (*C. L. Berger & Sons, Inc.*)

hairs will move across the image when the eye is moved, just as is the case in observing two objects at different distances with the naked eye. Under these conditions, parallax exists, and the direction of the sight is not fixed. When the telescope is properly focused, however, the cross hairs will always appear superimposed on the same point on the object no matter how the eye is moved and therefore the telescopic sight will have a definite direction.



(B)

Fig. 12.—The lens arrangement and the path of a pencil of light rays in exterior-focusing telescopes: (*A*) erecting type; (*B*) inverting type. (*C. L. Berger & Sons, Inc.*)

87. Some transit telescopes are focused by moving a concave lens on a slide behind the main lens. The optical principle involved is shown in Fig. 7, Chap. XIII. The general principles of the optical line of sight are not changed by this device; but the optics are improved, and by having a fixed objective lens the telescope tube can be made more nearly dust-tight. These telescopes are called **internal-focusing telescopes.**

88. A straight line from any point on the image through the optical center of the objective lens will strike a corresponding point on the object. A straight line from the cross hairs through the optical center of the lens will strike the point on the object where the observer sees the cross hairs apparently located. Thus the line of sight of a telescopic sight is defined by the cross hairs and the optical center of the objective.

As stated above, when a telescopic sight is properly focused the observer can move his eye slightly without changing the position of the cross hairs on the object. This differs in principle from a rifle sight, for the eye must be accurately aligned with the latter in order to determine where it is pointing. The telescopic sight on a transit also magnifies the object about 25 diameters. The diameter of the field of view is therefore very small, about 1 deg or 1.75 feet at 100 feet. Since the image formed by the lens is inverted, it is usual to design the eyepiece so that it erects the inverted image. Such an eyepiece is called an erecting eyepiece. When

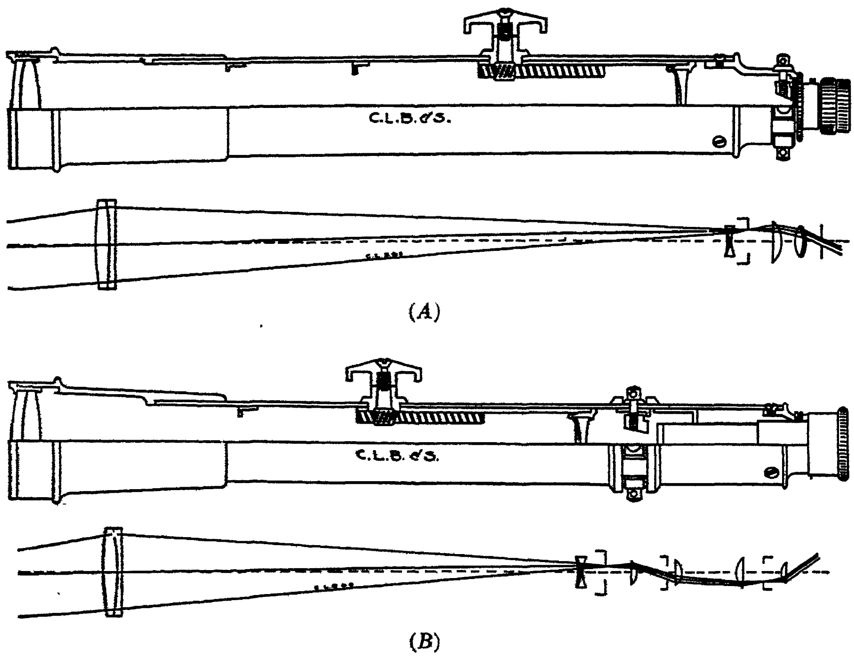


FIG. 13.—The lens arrangement and the path of a pencil of light rays in interior-focusing telescopes: (A) inverting type; (B) erecting type. (*C. L. Berger & Sons, Inc.*)

the eyepiece does not erect the image, it is called an inverting eyepiece. Inverting eyepieces require only two lenses instead of four and therefore give better results as they absorb less light and have other optical advantages. It takes only a short time to become accustomed to using them.

89. Verniers. Verniers in general are devices for determining readings smaller than the smallest division on the scale with which they operate. When the graduated circle is marked off in half degrees, i.e., divisions 30 minutes in length, it is usual to design the verniers so that the direction of the alidade can be read to 1 minute. In this case each vernier

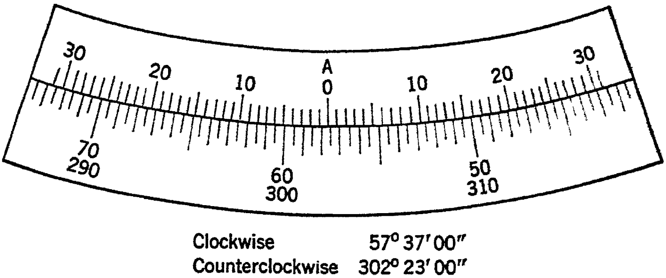


FIG. 14.—Double 1-minute vernier.

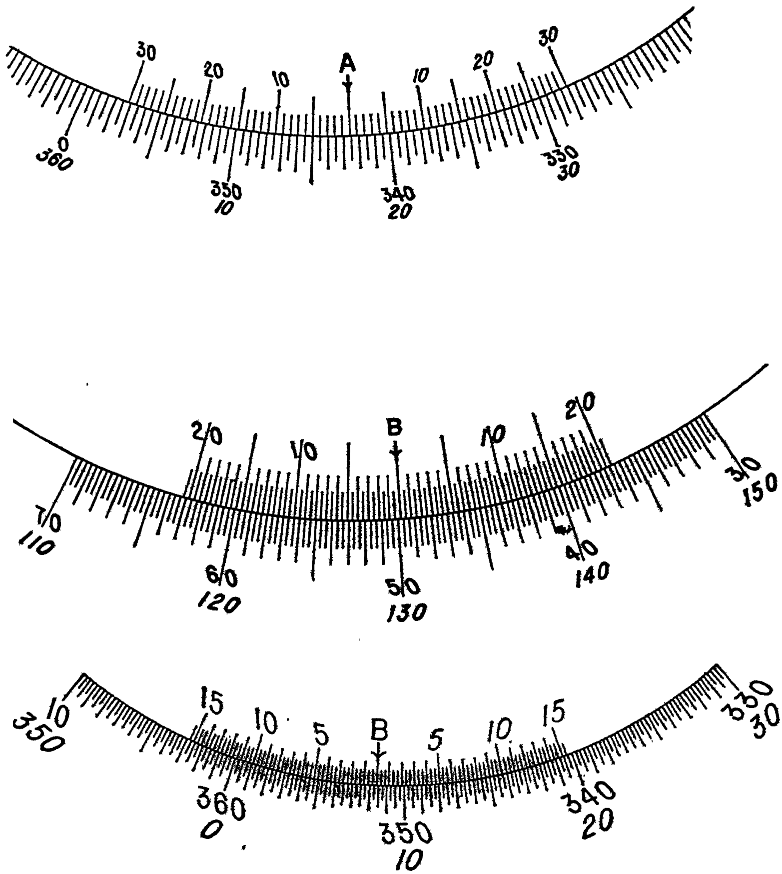
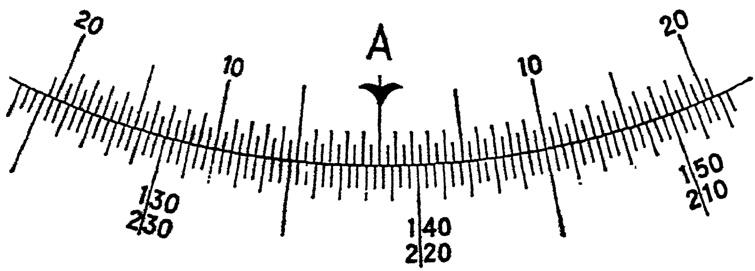


FIG. 15.—Typical verniers and scales: double verniers. (*Keuffel & Esser Co.*)

consists of a series of 30 divisions, each division being $\frac{1}{30}$ shorter than a division on the graduated circle so that the whole vernier scale of 30 divisions covers exactly 29 divisions of the graduated circle.

Assume that the zero graduation of the vernier coincided with the 57°30′ graduation of the circle; the reading would be 57°30′ (see Fig. 14). When the alidade is turned 1 minute of arc ($\frac{1}{30}$ of a division on the circle), the next graduation on the vernier will coincide with a graduation on the circle. The reading will then be 57°30′ plus 1 minute (as shown by the



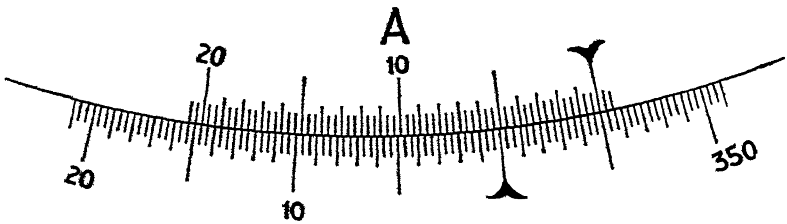


FIG. 16.—Typical verniers and scales. (*C. L. Berger & Sons, Inc.*)

vernier) i.e., 57°31′. Likewise, when the alidade is turned 7 minutes of arc, the seventh-minute graduation on the vernier will coincide with a graduation of the circle and the angle will be read 57°37′, etc. The vernier described above is called a 1-minute vernier, and a transit with such a vernier is called a 1-minute transit.

90. Ordinarily **double verniers** are used having complete sets of divisions running both ways from a common zero line. With such verniers, directions can be read clockwise or counterclockwise whenever desired. Since the verniers are placed to be read from the part of the circle nearest the observer, a clockwise angle is read from right to left.

In that case the set of divisions on the vernier to the left of the central zero mark are used.

91. The patterns of lines on the graduated circles and the verniers have become standardized. The circle described above will have three lengths of lines. The longest lines mark the 5-deg graduations, the lines of the next length mark the 1-deg graduations, and the shortest lines are used for the ½-deg positions. The 10-deg positions are numbered. Each 10-deg position (except zero) has two numbers, one for the clockwise direction and one for the counterclockwise direction. Other systems of enumeration are used.

92. Two lengths of lines are used for the 1-minute verniers described above, the longer length to mark the 5-minute graduations and the shorter

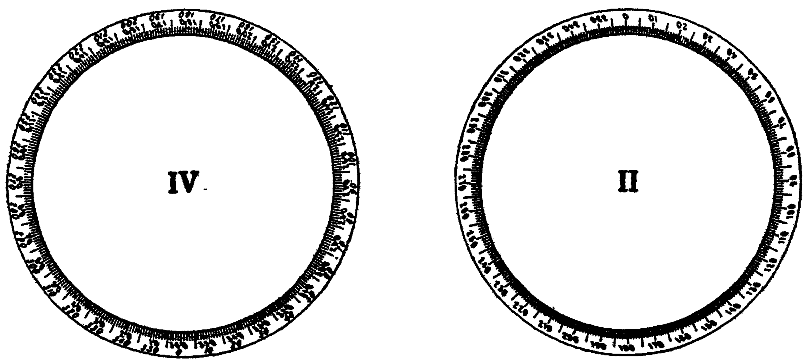


FIG. 17.—Usual methods of marking the graduated circle. (*Keuffel & Esser Co.*)

to mark the 1-minute positions. The 10-minute positions are appropriately numbered.

93. The arrangement of vernier and scale described above is probably the most generally used. Another common form is the 20-second vernier (see Fig. 19). The circle is divided into thirds of a degree (20 minutes), and the vernier is divided into 20 one-minute divisions, each of which is in turn divided into thirds (20 seconds). Since it is necessary to show each 20-second movement of the alidade and the smallest division of the circle is ⅓ deg, a movement of $\frac{1}{60}$ of the circle divisions must be shown (20 seconds is $\frac{1}{60}$ of ⅓ deg). Hence each of the smallest divisions on the vernier (the 20-second divisions) is $\frac{1}{60}$ shorter than each of the smallest division on the circle (the ⅓-deg divisions).

94. Reading the Vernier. As is the case of all scales, vernier readings should be estimated to a higher degree of precision than the reading of the scale. Consider a **1-minute** vernier that at first reads 60°20′ exactly. As the alidade is turned, the angle will increase gradually

from 60°20′ to 60°21′. When it has moved halfway, the vernier line representing 20 minutes will have moved beyond the line on the graduated scale corresponding to it, but the line 21 minutes will not have reached the graduated line with which it will correspond. **Both** lines will be **between**

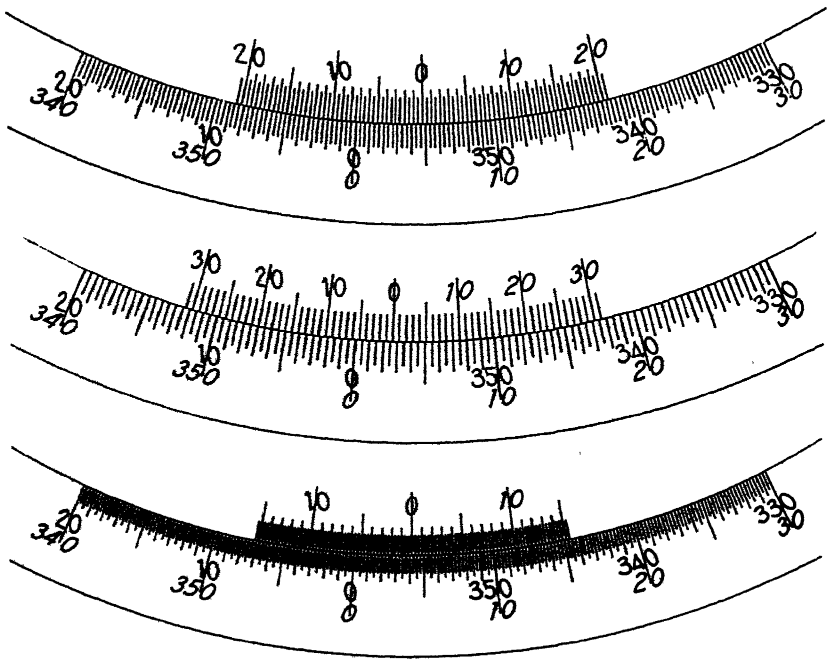
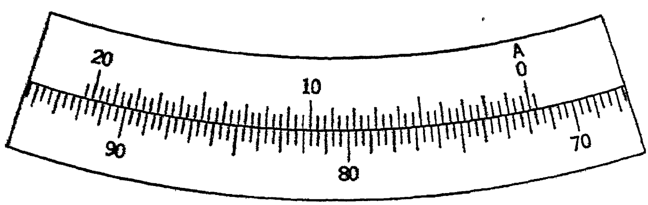


FIG. 18.—Verniers and scales. (*W. & L. E. Gurley.*)



Reading 71° 52′ 40″

FIG. 19.—Single 20-second vernier.

adjacent lines on the graduated circle. If they appear to be equally spaced between them, the reading is 60°20′30″. If the 20-minute mark has only just moved off its line but the 21-minute line has quite a distance to go, the reading is 60°20′15″. When the 20-minute line has moved well beyond its line and the 21-minute line has almost reached its

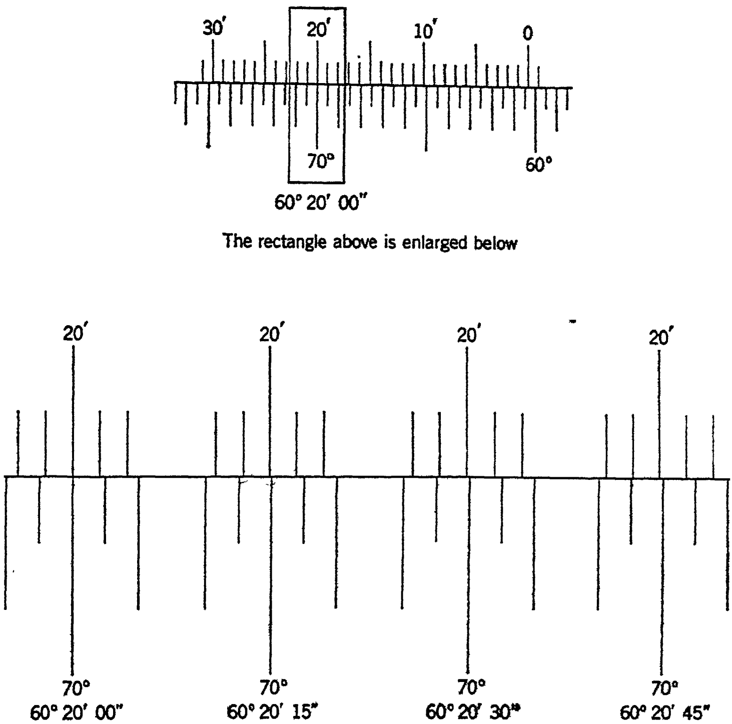


FIG. 20.—Reading a 1-minute vernier to 15 seconds.

line, the reading is 60°20′45″ (see Fig. 20). Closer estimates are not used. Verniers reading to 20 seconds are read to 10 seconds and no closer. In general, more precise verniers are read to one-half the least reading.

95. Plate Levels. Two small spirit levels are mounted on the alidade and adjusted to read zero when the vertical axis is vertical. They are used to obtain this condition when the instrument is being set up.

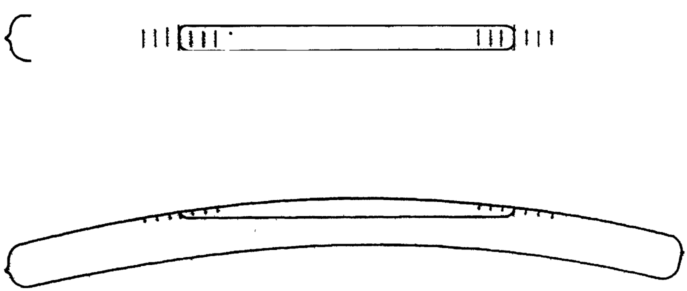


FIG. 21.—A level vial showing the curvature exaggerated.

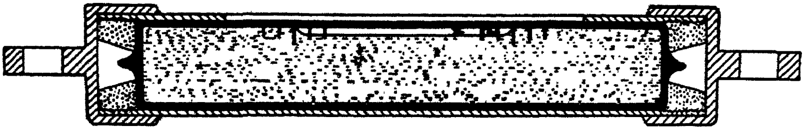


FIG. 22.—Cross section of a level tube showing the mounting of the vial. Dotted material is plaster of paris. (*C. L. Berger & Sons, Inc.*)

96. Principles of a Spirit Level. A spirit level consists of a curved glass tube partly filled with a volatile spirit like alcohol or ether. The tube is mounted with the high part in the center. Several graduations at each end of the bubble are placed near or etched on the tube so that as the spirit expands or contracts with temperature variations the ends of the

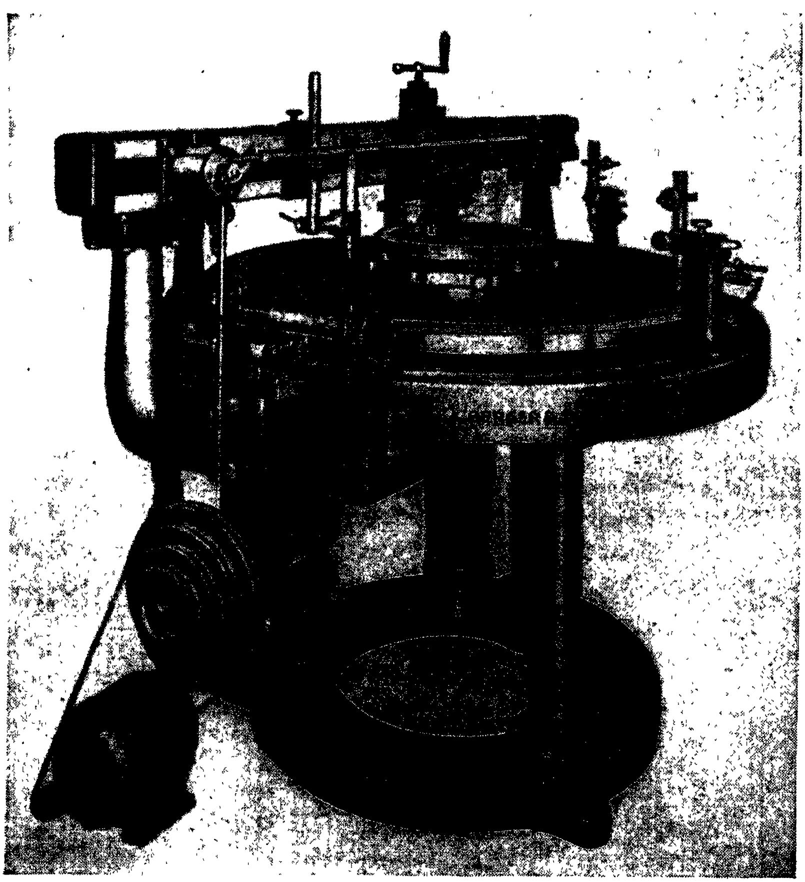


FIG. 23.—A graduating engine used for dividing circles at the Berger plant. (*C. L. Berger & Sons, Inc.*)

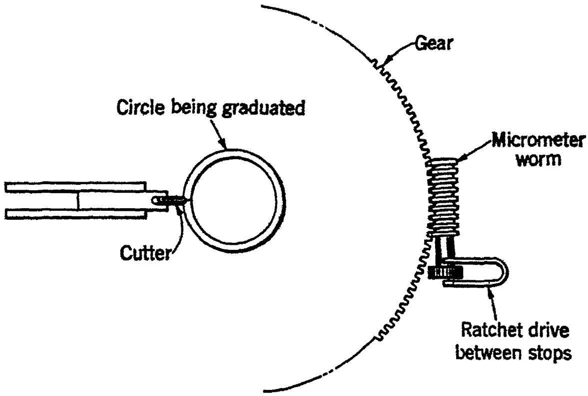


FIG. 24.—Schematic diagram of a graduating engine.

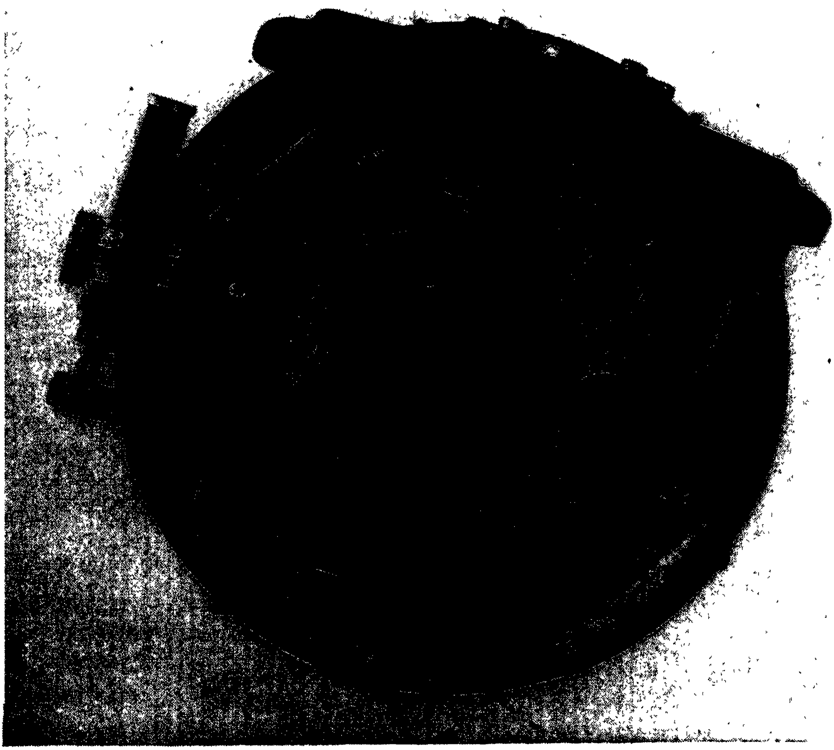


FIG. 25.—Looking down from above on a transit. (*Keuffel & Esser Co.*)

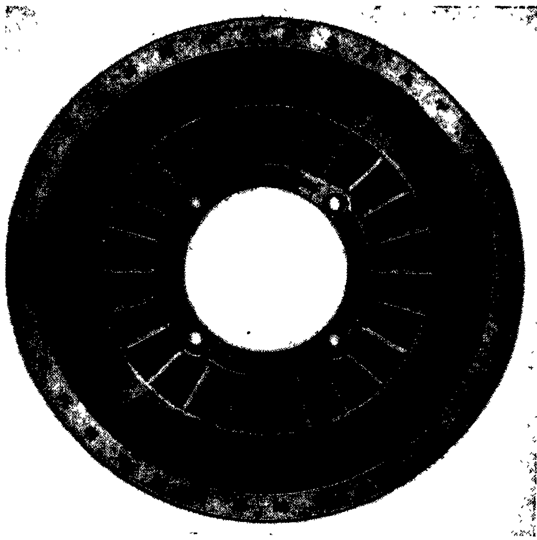


FIG. 26.—The lower plate with graduated circle. (*C. L. Berger & Sons, Inc.*)

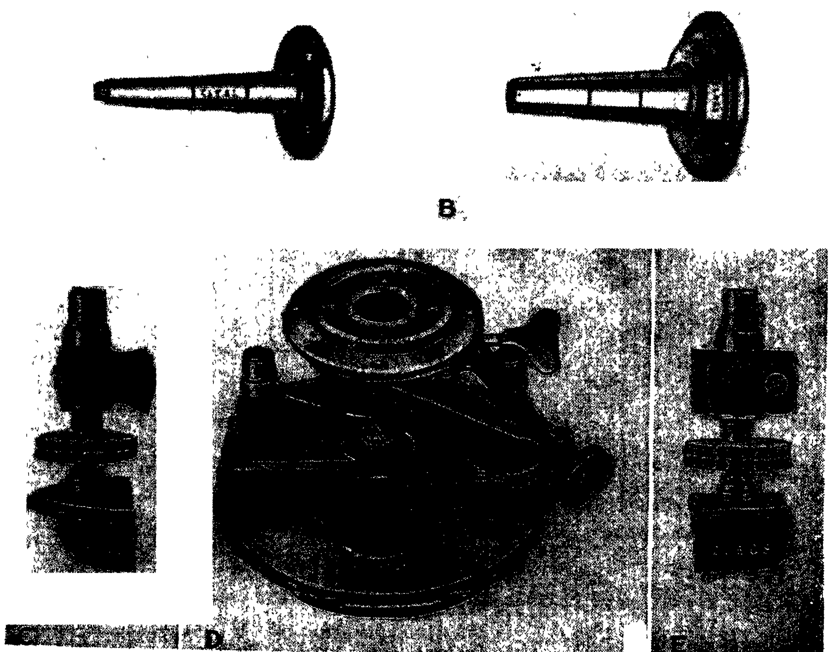


FIG. 27.—Berger four-screw leveling base for transits. (*C. L. Berger & Sons, Inc.*)

bubble can be placed at corresponding graduations and the same direction of the tube with respect to gravity can always be obtained (see Fig. 21).

97. The Horizontal Graduated Circle. The graduated circle is graduated automatically on a large wheel. Modern graduating engines (see Fig. 23) usually space the graduations very uniformly; but the circle can never be exactly centered on the wheel, and therefore the graduations on one part of the circle are usually slightly nearer together than the graduations on the opposite side of the circle. When an angle is read by

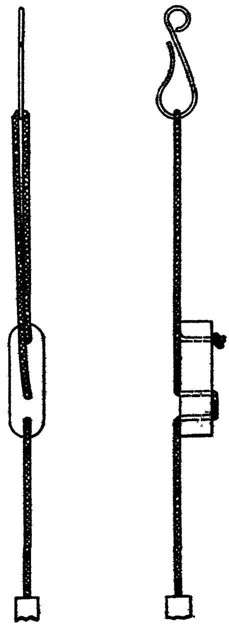


Fig. 28.—Plumb-cord adjusting device.

averaging the readings of the two verniers 180 deg apart, the effect of this **eccentricity** of graduation is eliminated because, if the *A* vernier travels over graduations that are too near together, the *B* vernier will travel over graduations proportionately too far apart. The very fact of reading two verniers increases the accuracy by using an average instead of a single reading. For accurate results, therefore, both verniers should be used.

98. The Leveling Head. The leveling head has four leveling screws, which are operated in pairs. When any two **adjacent** leveling screws are turned counterclockwise, the shifting plate drops away from the underside of the footplate. The shifting plate then can move freely about the

ball-and-socket joint. If the head is lifted in this condition, the whole instrument will move freely upward until the shifting plate comes in contact with the underside of the footplate. In this condition the instrument can be shifted horizontally about $\frac{3}{8}$ inch in any direction. This process is used to bring the instrument exactly over a point. Pairs of **opposite** leveling screws are turned simultaneously to level the instrument. First one pair is used and then the other. The two screws in a pair are turned simultaneously in opposite directions, maintaining a slight

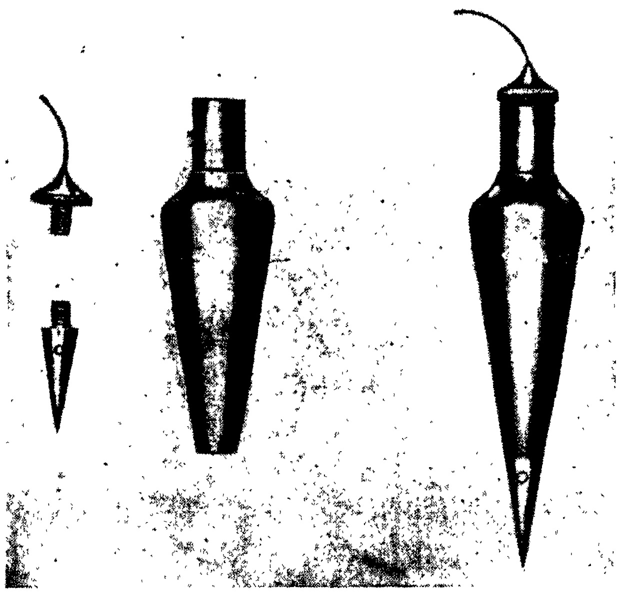


FIG. 29.—The parts of a plumb bob taken apart and assembled. (*C. L. Berger & Sons, Inc.*)

but firm pressure on the footplate. If the pressure of one pair is too great, both pairs will turn with considerable friction.

99. The Clamps. The **upper clamp** clamps the graduated circle to the alidade. The **lower clamp** clamps the graduated circle to the leveling head. After a clamp is tightened, the appropriate **tangent screw** will give a slow motion between the two parts clamped together. The upper clamp consists of a screw that drives a small brake shoe against a drum on the graduated circle. The frame that holds the screw carries a dog, which comes between the upper tangent screw and opposing spring, both mounted on the alidade. The lower clamp consists of a screw that tightens a band around a drum, also on the graduated circle. The frame

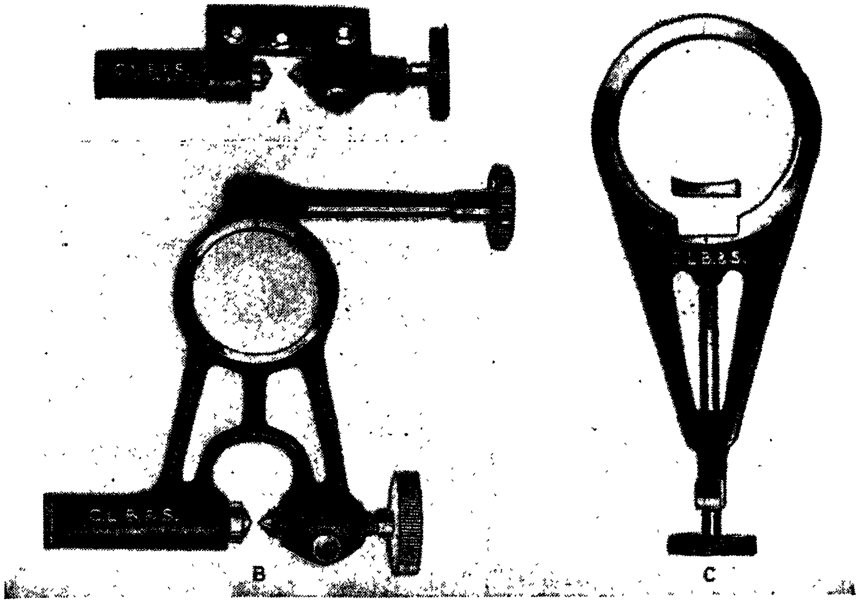
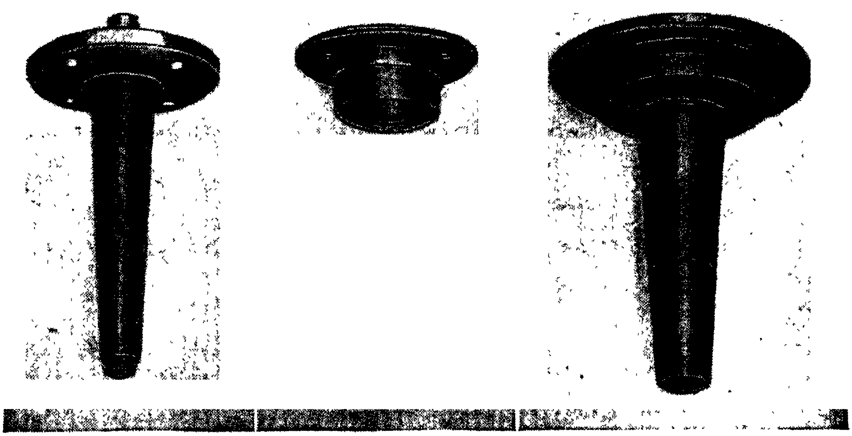


FIG. 30.—The clamps shown act on a pair of drums on the lower plate that supports the graduated circle. (*A*) Upper tangent screw. (*B*) Lower motion. (*C*) Lower clamp. (*C. L. Berger & Sons, Inc.*)



Inner Center Clamp Collar Outer Center

FIG. 31.—The parts that create the vertical axis in a transit. (*C. L. Berger & Sons, Inc.*)

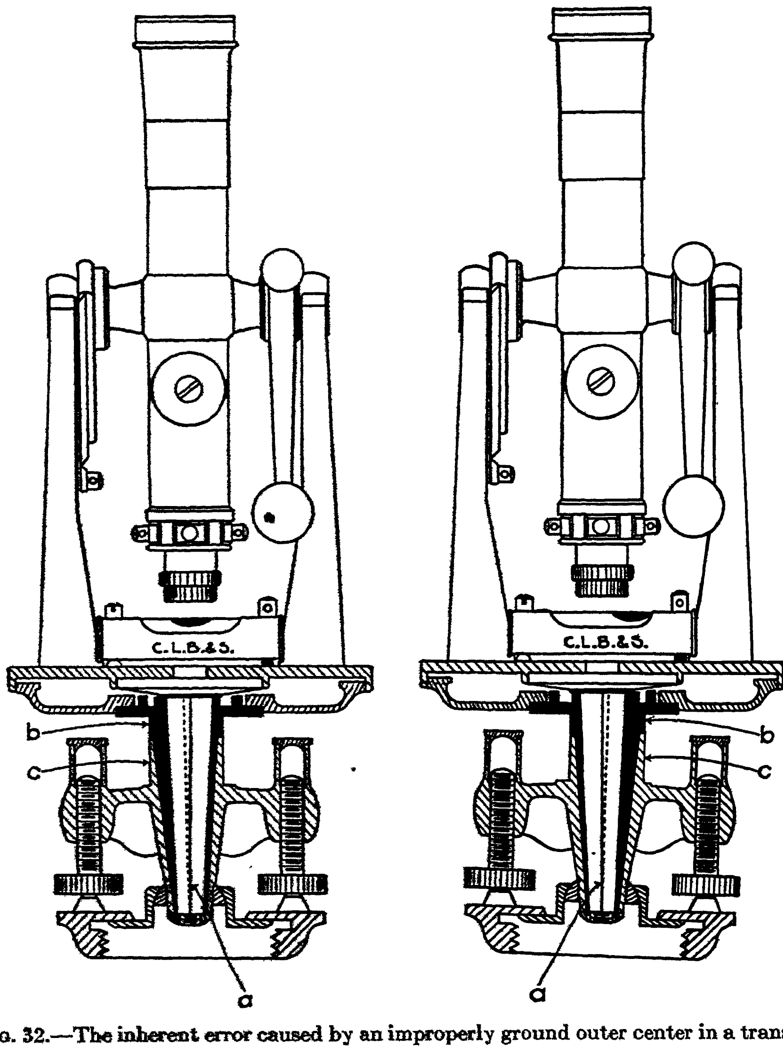


FIG. 32.—The inherent error caused by an improperly ground outer center in a transit. (*C. L. Berger & Sons, Inc.*)

that holds the screw carries the lower tangent screw and opposing spring. A dog on the leveling head comes between the screw and spring.

100. The act of tightening a clamp, especially the lower clamp, sometimes turns the instrument slightly. Therefore a clamp should not be touched after the tangent screw has been set.

101. Auxiliary Equipment. Most engineer's transits are equipped with a level tube attached to the telescope that is adjusted to read zero when the line of sight is level. The transit can then be used as a level. These transits usually have a vertical circle attached to the horizontal axis and a vernier to read the vertical angle attached to a standard. A clamp called the **vertical clamp** and its slow motion are used to direct the telescope up and down. A magnetic compass is often mounted in the center of the transit.

102. Geometry of the Transit. The following geometrical requirements must be maintained in a transit:

1. The inner and outer spindle and the bearings of the horizontal axis must be so made that the instrument turns about geometric lines, not cylinders or cones.
2. The vertical axis, horizontal axis, and line of sight must meet in a point called the **instrument center.**
3. The horizontal axis must be perpendicular to the vertical axis.
4. The line of sight must be perpendicular to the horizontal axis. The objective lens must therefore slide along a straight line perpendicular to the horizontal axis.
5. The plate bubbles must read zero when the vertical axis is vertical.
6. The telescope bubble must read zero when the line of sight is horizontal.
7. The horizontal graduated circle must be concentric with and perpendicular to the vertical axis.
8. The graduations on the horizontal graduated circle must be concentric with the vertical axis.
9. The vertical circle must be concentric with and perpendicular to the horizontal axis.
10. The graduations on the vertical circle must be concentric with the horizontal axis.
11. The vertical circle must read zero when the line of sight is perpendicular to the vertical axis.

PROBLEMS

1. Record the readings (in both directions if possible) of all verniers shown in this chapter.

2–7. Construct a vernier and scale for the following conditions, make the lines the proper lengths, and include the proper numbering. Instead of an arc use a straight line between vernier and scale, and space graduations only by eye.

	Smallest circle graduation	Least reading of vernier	Clockwise reading
2	30′	1′	25°42′
3	20′	20″	32°54′20″
4	20′	30″	54°42′30″
5	30′	1′	82°17′
6	20′	20″	74°39′10″
7	20′	30″	45°14′30″

8–18. For each of the geometric conditions of the transit listed below state the following: (*a*) What angles will be affected most? (*b*) What angles will be affected slightly? (*c*) In each case, will the angular error be greater when the points observed are nearer the transit? (*d*) What field procedure will eliminate the error introduced?

8. Line of sight above the horizontal axis.

9. Line of sight to the left of the vertical axis.

10. The horizontal axis behind the vertical axis.

11. The horizontal axis not perpendicular to the vertical axis.

12. The line of sight not perpendicular to the horizontal axis.

13. The objective slide not perpendicular to the horizontal axis.

14. The plate bubbles not reading zero when the vertical axis is vertical.

15. The telescope bubble not reading zero when the line of sight is horizontal.

16. The graduations on the graduated circle not concentric with the vertical axis.

17. The graduations on the vertical circle not concentric with the horizontal axis.

18. The vertical circle reading a +5 minutes when the line of sight is perpendicular to the vertical axis.

CHAPTER V

USE OF THE TRANSIT

103. To Use the Transit to Best Advantage. The secret of successful use of the transit is the formation of a set of standard habits based upon the ever-present necessity for speed and upon a clear knowledge of exactly what the transit does. Poor results are due mainly to ignorance, although partly to clumsiness.

FIG. 1.—A Gurley engineer's transit. (*W. & L. E. Gurley.*)

PRELIMINARY PROCEDURE

104. To Place the Transit on the Tripod. Adjust the friction of the tripod legs at the tripod head. The legs should fall slowly of their own weight from a horizontal position. Set up the tripod with the legs well spread and pressed firmly into

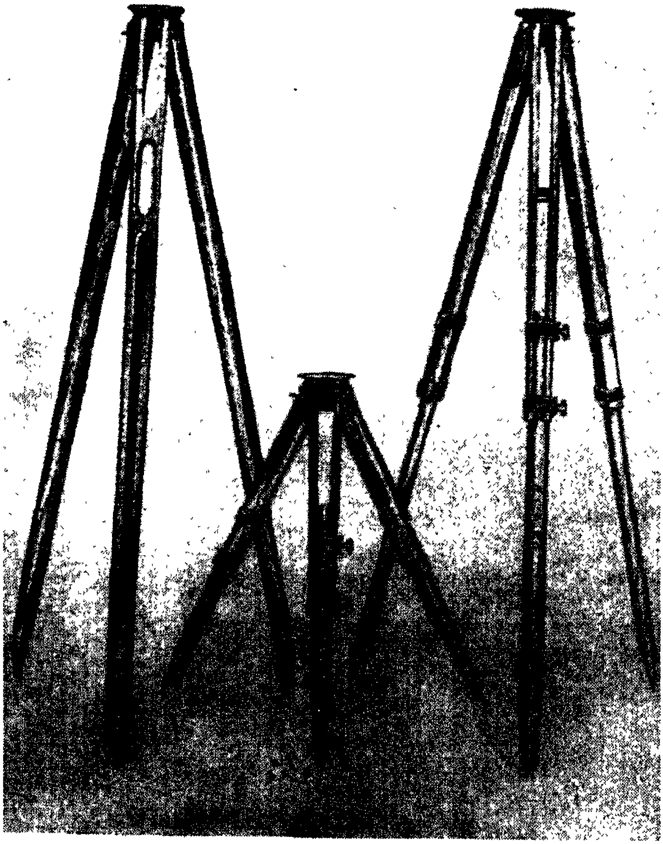


FIG. 2.—**Instrument tripods.** (*C. L. Berger & Sons, Inc.*)

the ground. Remove the instrument from the case, and, lifting it by the base, immediately screw it firmly on the tripod.

105. To Carry the Transit. Hold the transit on the shoulder in a horizontal position, instrument to the rear, and balanced to carry the weight of the arm. When overhead obstructions exist, carry the transit under the arm, balanced in a horizontal position with the instrument forward (Fig. 4).

106. To Set Up the Transit over a Point. Proceed according to the following

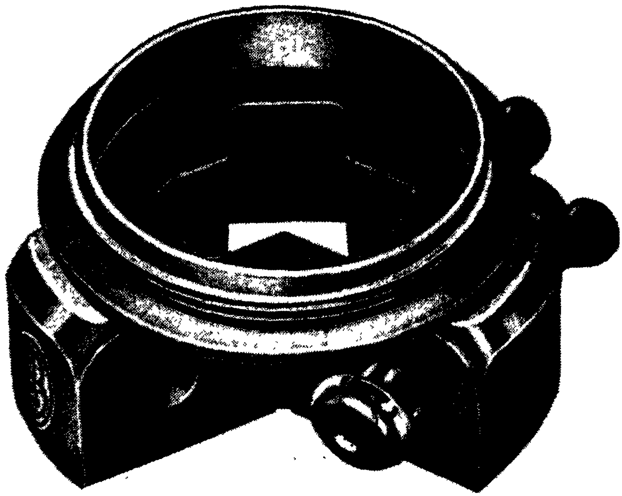


FIG. 3.—The usual type of tripod head. (*C. L. Berger & Sons, Inc.*)

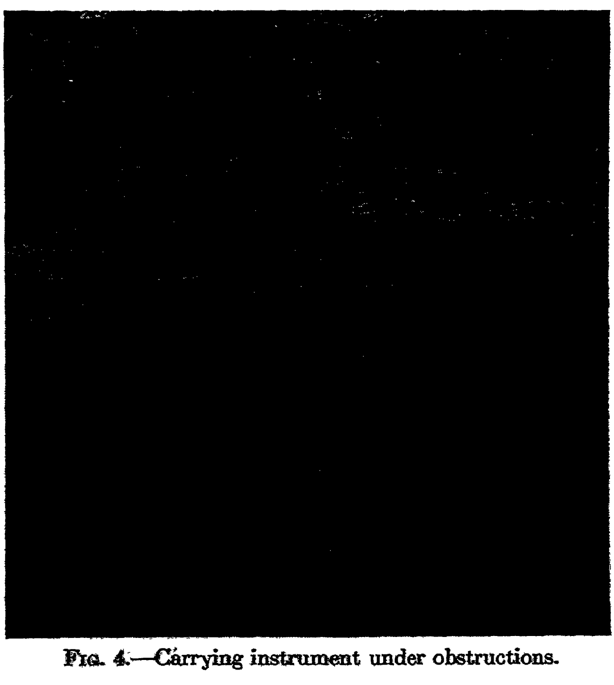


FIG. 4.—Carrying instrument under obstructions.

FIG. 5.—Stand 24 inches downhill.

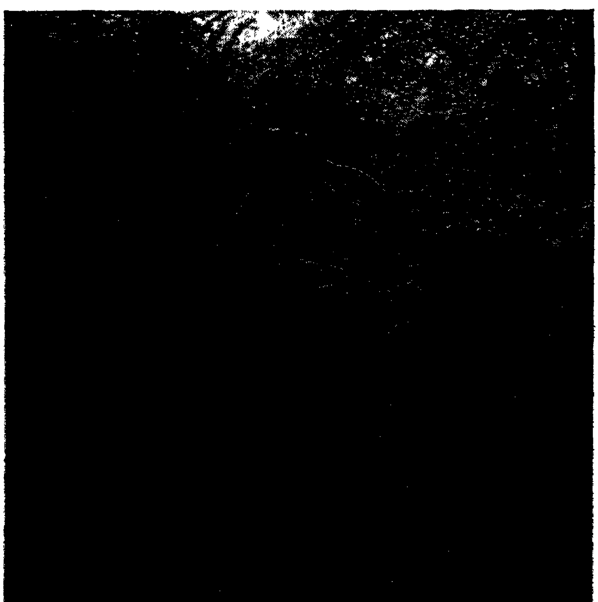


FIG. 6.—Seize two legs and place third leg 24 inches uphill.

1. Stand 24 inches downhill facing the point over which the transit is to be set up. Seize two legs, and place the third leg on the ground 24 inches uphill from the point. Pull the other two legs outward and backward, and place them on the ground so that the footplate is nearly level. This step requires considerable skill and is the most important timesaver.

2. Attach the plumb bob. Move the transit bodily without changing the relative position of the legs, so that the bob hangs within 2 or 3 inches of the point.

3. Push each leg firmly into the ground. To accomplish this, walk around the transit to each leg, and grasp the leg about 18 inches from the foot. Raise or lower

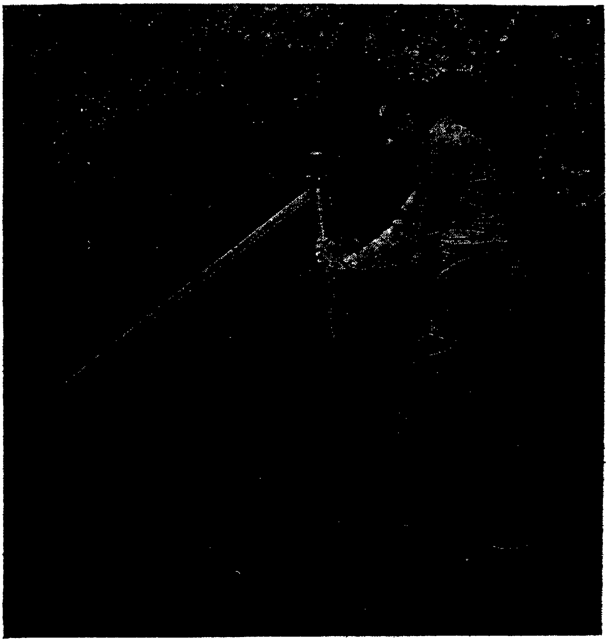


FIG. 7.—Pull two legs outward and backward placing them on ground so that foot plate is nearly level.

the plumb bob until it hangs about 1 inch above the point. It will probably be about 2 or 3 inches one side of the point.

Choose the leg that is most nearly on the opposite side of the point from the plumb bob. By pushing this leg farther into the ground or moving it outward and then pushing it into the ground, move the plumb bob until it is exactly opposite a second leg. Move the second leg until the bob comes within ¼ inch of the point.

In setting up on a pavement or on masonry the legs can be moved in either direction, thus simplifying the procedure. The points of the tripod shoes should be placed in cracks or other indentations to prevent slipping (see Fig. 12). On smooth hard surfaces small notches must be cut for the points with a cold chisel.

4. Loosen two adjacent leveling screws. This loosens all the leveling screws. Level instrument roughly without setting the screws tighter. To level an instrument

turn it until the plate levels are in line with pairs of **opposite** leveling screws. Then turn the leveling screws according to the old rule: "Thumbs in, thumbs out, the bubble follows the left thumb" (see Fig. 14). Slide the head until the plumb bob is over the point, i.e., until the center of the small ellipse in which it swings is over the point.

5. Level the instrument. The leveling screws should have been left rather loose when the instrument was shifted over the exact point. While leveling accurately the screws should be tightened gradually as the leveling progresses. The tightness can be regulated by the relative motions of the pair of screws being used. Leave

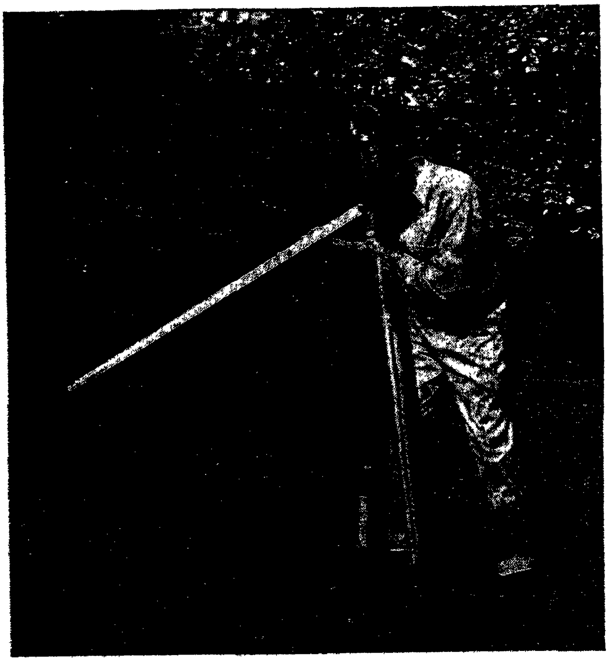


FIG. 8.—Move transit bodily until bob hangs within 2 inches or 3 inches of point and push legs firmly into ground.

the screws firm, but not bound. If they bind in leveling, loosen an **adjacent** screw. It must be remembered that when one pair of leveling screws is being used the other pair is often being forced tightly against the footplate or else being forced to slide over the surface of the footplate.

When the bubbles have been centered, turn the instrument 180 deg in azimuth. If the bubbles do not again center, the levels are not in adjustment. Bring the bubbles halfway toward the center with the leveling screws. The vertical axis will now be vertical (the desired condition), and the bubbles will remain in this new position in whatever direction the instrument is pointed.

If this procedure is followed, setting up the transit takes 1 or 2 minutes. The usual mistake is to disregard the importance of Steps 1, 2, and 3.

FIG. 9.—After pushing each leg firmly into ground move leg opposite plumb bob outward until bob is opposite a second leg.

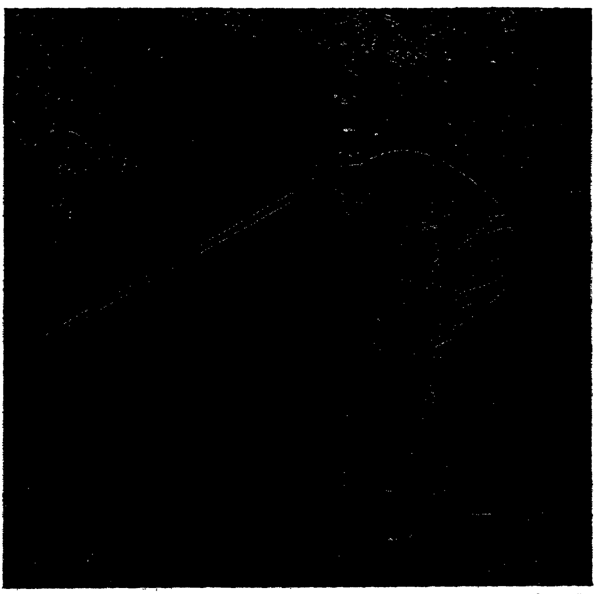


FIG. 10.—Move second leg outward until bob moves within ¼ inch of point.

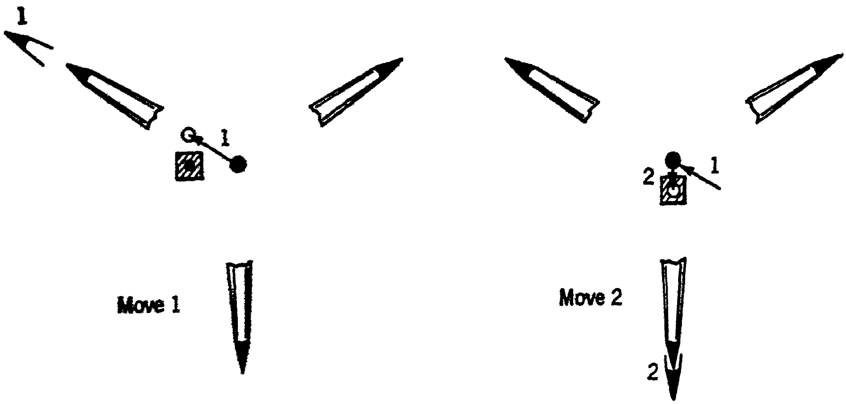


FIG. 11.—Method of moving the legs.

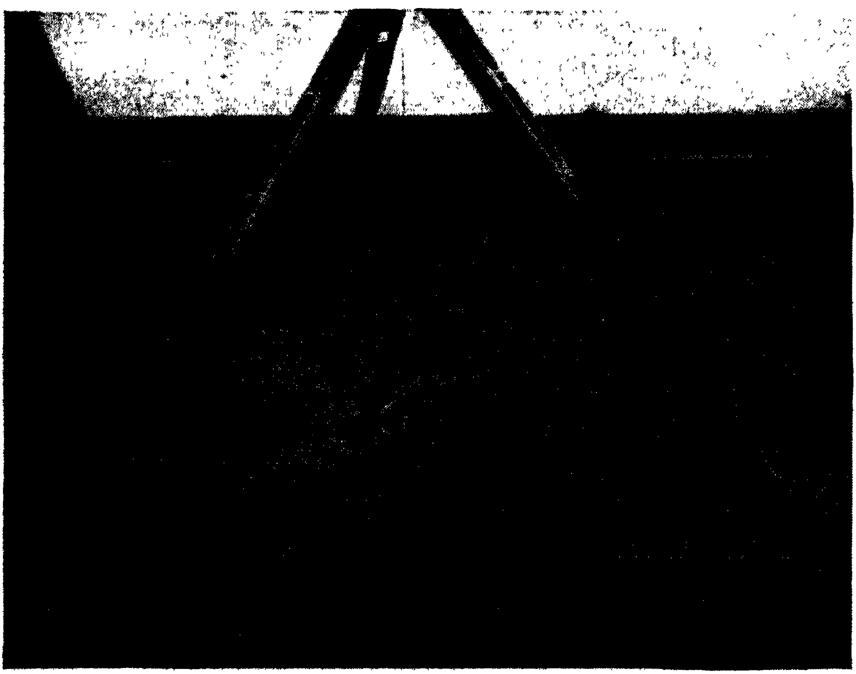


FIG. 12.—Tripod shoes placed in cracks to avoid slipping.

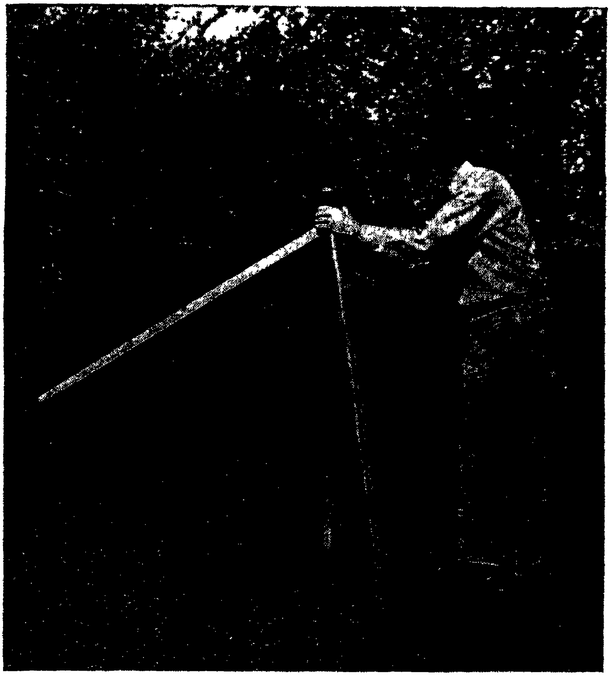


FIG. 13.—After rough leveling, slide head until bob is over tack.

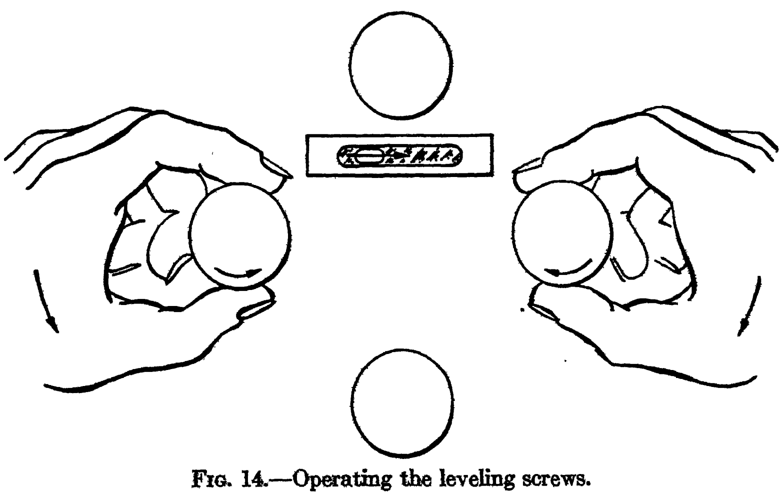


FIG. 14.—Operating the leveling screws.

FIG. 15.—Leveling the instrument. A soldier setting up a Gurley transit in Germany. (*W. & L. E. Gurley and U.S. Army Signal Corps.*)

TO MEASURE A HORIZONTAL ANGLE

107. Precautions to Be Observed while Operating the Transit. Once the transit has been set up, do not touch it or allow anything to touch it except when and where it is necessary for operating it. Never straddle the legs, but always stand between them. Be particularly careful not to kick or touch the tripod while walking around it.

108. Abbreviations. The abbreviations used are as follows:

U.C., upper clamp.

U.T., upper tangent screw.

U.M., upper motion (U.C. and U.T. combined).

L.C., L.T., L.M., same for lower motion.

109. Definitions. To point a target or signal means to bring the cross hairs on it. To transit, plunge, reverse, dump, or flop means to turn the telescope upside down. The normal position is direct D; the

upside-down position is reverse R. To traverse the instrument, or to turn it in azimuth, means to turn it about the vertical axis.

110. Use of the Clamps. To set an angle on the circle or to point a signal, first choose the proper motion to use, loosen the clamp, bring the instrument approximately into position, clamp it, and make a fine adjustment with the tangent screw. Some authorities advise bringing the instrument on with a final clockwise motion of the tangent screw, thus moving the instrument with the screw rather than allowing the opposing spring to move the instrument.

111. To Set the Vernier at Zero. Loosen U.C. and L.C. Turn the instrument so that there is good light on the vernier. By pressing the finger up against the circle turn it until the zero is nearly in position, clamp the U.C., and bring it in position with the U.T., using a reading glass.

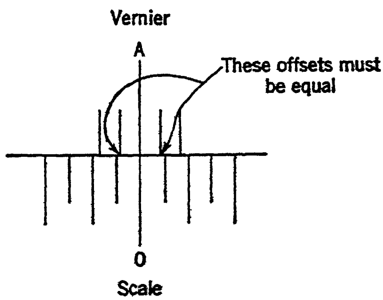


FIG. 16.—Setting vernier at zero.

With the aid of the reading glass, make the two lines adjacent to the vernier zero have equal offsets from their opposites on the scale (see Fig. 16).

112. To Focus the Eyepiece. The eyepiece must be focused according to the eyesight of the observer. Errors due to parallax will occur if this is neglected. Point the telescope at a bright, unmarked object, like the sky. Focus the eyepiece until the cross hairs are clear-cut. Then focus the objective on some well-defined point, and move the head left and right or up and down. If the cross hairs do not remain on the point, change the eyepiece focus until the apparent relative motion is reversed. Continue focusing back and forth, reducing the relative motion each time until it is eliminated.

113. To Point the Instrument. The vertical clamp should not be used if only horizontal angles are being measured. The bearings of the horizontal axis should be just tight enough to retain the up-and-down direction of the telescope without noticeable friction. If they are too loose, tighten the vertical clamp to obtain this condition.

114. In pointing the instrument, one and only one horizontal clamp is ever free. The L.C. is always freed in starting to point on the first side of the angle, and the U.C. is always freed in starting to point on the other side of the angle.

115. Place the fingers of one hand on the proper clamp, loosen it, and continue to hold it with that hand. By holding the eyepiece with the thumb and forefinger of the other hand, aim the telescope at the point to be observed by looking along the top of the telescope and then through it (Fig. 17). Tighten the clamp with the first hand, and take hold of the

FIG. 17.—Bringing cross hairs near point.

corresponding tangent screw. Focus the objective, and bring the vertical cross hair on the point with the tangent screw.

116. To Read the Vernier. Estimate the reading of the vernier to minutes with the naked eye, and then make the complete reading with the aid of the reading glass. To use the reading glass, steady the hand on the transit, holding the glass about 2½ inches from the vernier and **in line with the graduation being read** (Fig. 19). When both the *A* and *B* verniers are used, only the minutes and seconds are read on the *B* vernier. The degrees, minutes, and seconds on the *A* vernier are recorded and only the seconds on the *B* vernier. **When the minutes read on the *B* vernier are 1 minute less than on the *A* vernier, a bar is placed**

FIG. 18.—Bringing cross hairs on point with upper tangent motion. (*Keuffel Esser Co.*)

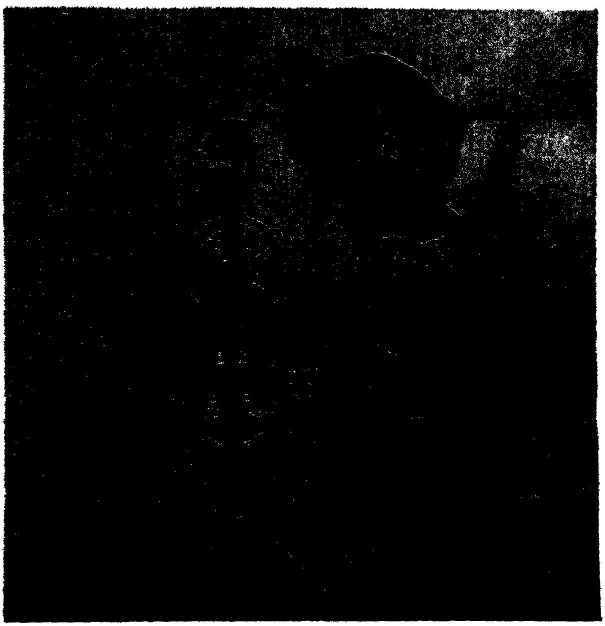


FIG. 19.—Using the reading glass.

above the seconds from the *B* vernier. When they are 1 minute more, 60 seconds is added to the seconds from the *B* vernier. The average of the minutes and seconds of the *A* and *B* verniers is immediately computed and recorded, the same notation being used. Three examples of this notation are shown below.

1. Assume
The reading on the *A* vernier, 12°10′15″.
The reading on the *B* vernier, 192°10′30″.
The field notes would be the following:

°	′			″ Aver.
		A	*B*	
12	10	15	30	22.5

This indicates 12°10′22.5″.
2. Assume
The reading on the *A* vernier, 12°10′15″.
The reading on the *B* vernier, 192°11′15″.
The field notes would be the following:

°	′	″		″ Aver.
		A	*B*	
12	10	15	75	45

This indicates 12°10′45″.
3. Assume
The reading on the *A* vernier, 12°10′15″.
The reading on the *B* vernier, 192°09′30″.
The field notes would be the following:

°	′	″		″ Aver.
		A	*B*	
12	10	15	$\overline{30}$	$\overline{52.5}$

This indicates 12°09′52.5″.

117. To Measure an Angle. If possible, angles should always be measured clockwise. In this discussion assume that the transit is at *A*, the left point is *B*, and the right point is *C* and that the angle is measured

from B to C (Fig. 20). When it is necessary to determine the value of the angle only to the nearest minute, the angle is "turned" only once and only the A vernier is used. The procedure is as follows:

1. Set vernier A at zero.
2. Point instrument at B, using L.M.
3. Point instrument at C, using U.M.
4. Loosen L.M.
5. Read A vernier clockwise.

118. If the counterclockwise angle had been read, the value of the **counterclockwise** angle from B to C would have been determined.

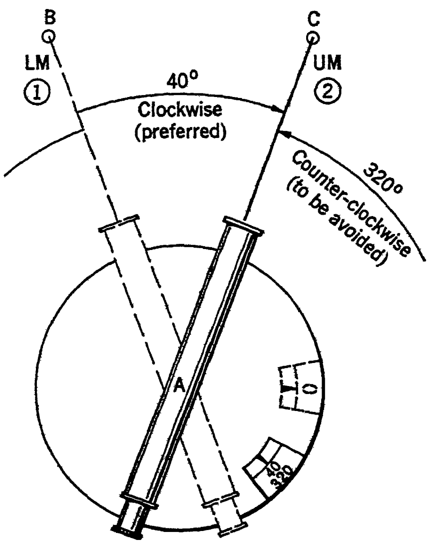


FIG. 20.—Measuring an angle from B to C, *i.e.*, angle A-BC.

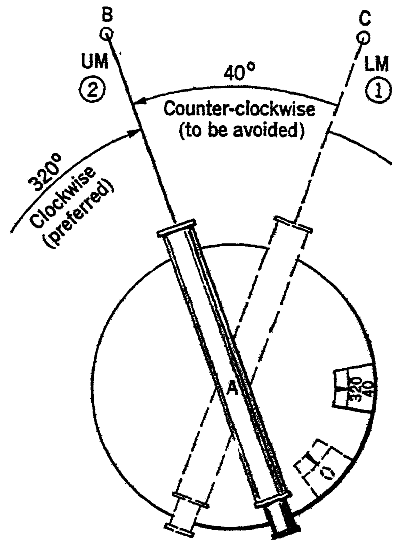


FIG. 21.—Measuring an angle from C to B, *i.e.*, angle A-CB.

This value should be avoided. Obviously the two angles are explements of each other, i.e., their sum is 360°, and they can be read simultaneously from one setting.

119. It will be noted that the lower motion must be used on the point first observed and the upper motion used on the second point. The angle shown by the vernier, whether read clockwise or counterclockwise, is always the **angle from the first or lower-motion point to the second or upper-motion point** (Figs. 20 and 21). It makes no difference in which direction the instrument is actually turned when either of the clamps is open, nor does it make any difference whether the telescope is direct or reversed. Of course, the telescope position, direct or reversed, must not be changed when the upper clamp is open as this will change the angle

read by 180 deg. It can, however, be changed when the lower clamp is open.

120. To Repeat an Angle (see Fig. 22). If, after the cycle described above is complete, the process is repeated without resetting the vernier, i.e., by beginning the cycle with Step 2, the value of another angle is added to the original reading. The value of the angle desired can then be determined by dividing by 2. Any number of repetitions can be made, the accuracy increasing with the number of repetitions. Usually the angle is turned once, twice, or six times or in multiples of 6. The telescope is reversed for the second half of the operation and all the systematic instrumental errors thus eliminated except errors in the adjustment of the plate bubbles and errors in the graduation of the circle. When the angle is turned six times, i.e., three with the telescope direct and three with the telescope reversed, the notation is 3 D.R. The value of the first turn is always read as a check against blunders in the final result. In repeating the angle it is easy to lose track of the number of turns. Each cycle ends when the lower clamp is loosened. Therefore when that point is reached the count should be made. **If the count is made out loud,** it will be remembered.

121. Reading the *B* Vernier. The accuracy can be nearly doubled by reading the *B* vernier as well as the *A* vernier. The eccentricity of the graduations is also eliminated by this means. When the *B* vernier is read, the value of the initial setting will be zero only by chance. The average of the *A* and *B* verniers thus constitutes an **initial reading,** which must be subtracted (algebraically) from all other readings.

122. Overrunning the Circle. When the angle or the number of repetitions is large, the total angle will often be greater than 360 deg, so that a certain multiple of 360 deg should theoretically be added to the actual reading. In practice, it has been found easier to neglect this until after dividing the actual reading by the number of repetitions. Then that multiple of the expression $360/t$ (where t is the number of turns) is added to the result necessary to make it agree closely with the 1D reading. The validity of this can be shown by the following equation:

$$\frac{360n + r}{t} = \frac{360}{t}n + \frac{r}{t}$$

where n = number of 360° added
r = reading
t = number of turns

For example, if the angle is turned 3 D.R., i.e., six times, the quotient $360°/t = 60°$. Therefore any multiple of 60 deg can be added to the result. If the 1D reading were 131 deg and the 3 D.R. reading were 66 deg, the following procedure would be followed:

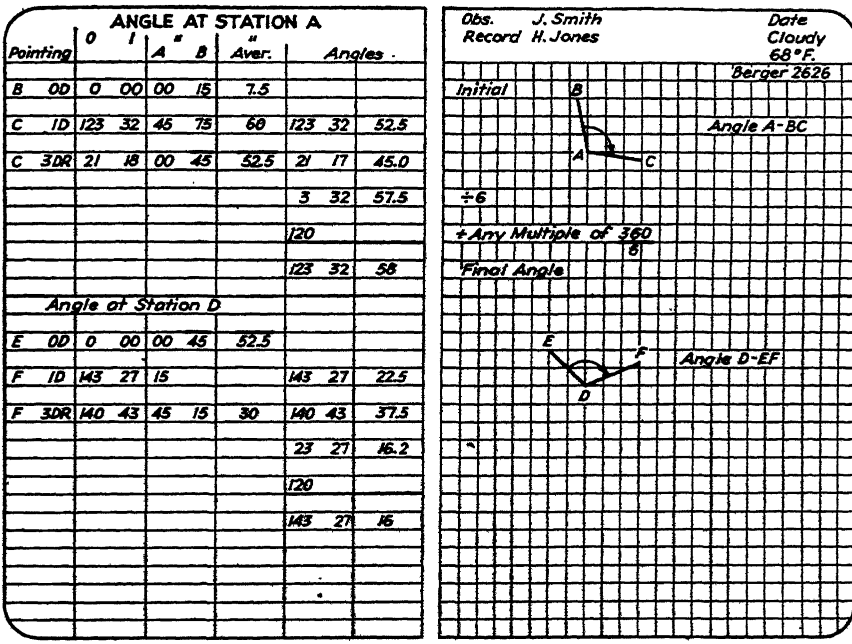
$$\begin{aligned} 66° \div 6 &= 11° \\ 2 \times 60 &= \underline{120} \\ \text{Sum} &= 131° \end{aligned}$$

123. Dividing by 6. Dividing by 6 may be accomplished as follows: Divide the degrees by 6, and use the remainder as the first digit of the minutes in the quotient. Divide the minutes by 6, using the quotient as the second digit of the minutes and the remainder as the first digit of the seconds. Divide the seconds by 6, using the result to fill out the seconds. For example, to divide 291°29′15″ by 6,

	291°29′15″	
Step 1	48 3	(291 ÷ 6 = 48 and 3 over)
Step 2	48 34 5	(29 ÷ 6 = 4 and 5 over)
Step 3	48 34 52.5	(15 ÷ 6 = 2.5)

124. Catching Blunders. The final angle should agree with the 1D value within about 15 seconds. If the difference is greater, a blunder has probably been made.

125. Example of Angle Notes. Figure 22 shows the field notes that result when angles are measured 3 D.R., both verniers being used.



ANGLE AT STATION A

Pointing	°	′	″ A	″ B	″ Aver.	Angles	
B 0D	0	00	00	15	7.5		
C 1D	123	32	45	75	60	123 32	52.5
C 3DR	21	18	00	45	52.5	21 17	45.0
						3 32	57.5
						120	
						123 32	58
Angle at Station D							
E 0D	0	00	00	45	52.5		
F 1D	143	27	15			143 27	22.5
F 3DR	140	43	45	15	30	140 43	37.5
						23 27	16.2
						120	
						143 27	16

Fig. 22.—Examples of field notes resulting from measuring angles 3 D.R.

126. Accuracy. Experience indicates that the results of 3 D.R. can be relied upon to be within 3 to 6 seconds of the true value, depending on the skill of the observer.

127. Closing the Horizon. Usually in triangulation and occasionally in traverse more than one angle is measured at a single station. A quick and useful check can then be obtained by measuring the unused

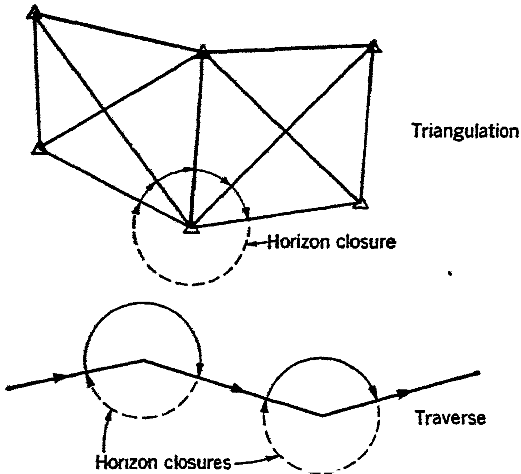


FIG. 23.—Horizon closures. Only the angles shown by full lines are required. The angles shown by dotted lines close the horizon so that station adjustments can be made.

STATION A

Pointing	°	′	″ A	″ B	″ Aver.	Angles		
B 0D	0	0	00	15	7.5			
C 1D	74	13	45			74	13	37.5
C 3DR	85	22	15	30	22.5	85	22	15
						14	13	42.5
						74	13	42.5
C 0D	0	0	00	30	45			
D 1D	158	48	00			158	48	15
D 3DR	232	49	30	15	22.5	232	49	37.5
						38	48	16.2
						158	48	16.2
D 0D	0	0	00	45	52.5			
B 1D	126	57	45			126	57	52.5
B 3DR	41	47	00	45	52.5	41	47	00
						6	57	50
						126	57	50

Obs. J. Smith Date
Record H. Jones Clear
60°F.

C, B, A, D

Sta. Adj.

					Adj. Angles
A-BC =					
	74	13	42.5	+3.8	74° 13′ 46.3″
A-CD =					
	158	48	16.2	+3.8	158° 48′ 20.0″
A-DB =					
	126	57	50	+3.7	126° 57′ 53.7″
	358	118	108.7	+11.3	358° 118′ 120.0″

FIG. 24.—Field notes for a horizon closure and a station adjustment.

angle that completes the circle, or **closes the horizon.** When this angle is measured, the angles can be adjusted so that their sum equals 360 deg. The same increment should be applied to each angle (including the unused angle) as the probable error is the same for each. Such an adjustment is called a **station adjustment** (see Fig. 23).

128. Often this procedure is applied to transverse angles where only one angle is used.

129. Example of Angle Notes for a Horizon Closure. Figure 24 shows the field notes that result from a horizon closure.

MISCELLANEOUS OPERATIONS

130. To Level the Transit Precisely. When the vertical axis of the transit does not accurately coincide with the direction of gravity, errors are introduced in the horizontal and vertical angles measured. The plate levels indicate the direction of the vertical axis with sufficient accuracy for the requirements of most observations. However, the plate levels should not be relied on when (1) the horizontal angle is to be measured between two points separated by an angle of elevation of 20 deg or more, (2) a vertical angle is to be measured more accurately than to the nearest 20 seconds, or (3) the transit is used to establish a vertical plane for controlling a jig or steel erection, etc.

131. For these requirements the transit must have a firm support. Stakes must be driven to support the legs if the ground is springy. The transit is leveled in the usual way, and the following procedure is carried out.

132. With the U.C., set the vernier approximately at zero. Using the L.C., clamp the instrument so that the telescope is parallel to a pair of opposite leveling screws. With the vertical motion, center the bubble in the tube attached to the telescope. Using the U.C. turn the instrument through 180 deg. If the telescope bubble does not center, bring it halfway back, using the vertical motion. Turn the instrument back to zero, and center the bubble, using the leveling screws. Repeat until the bubble remains centered at 0 and 180 deg. Turn 90 deg, and center the bubble with the leveling screws. Check all positions.

133. To Measure a Vertical Angle. Aim the cross hairs at the point, using the vertical motion, and read the vertical circle vernier. If the instrument is not known to be in adjustment, the observation should be made direct and reversed and the average used. This eliminates any error in the position of the vernier that might introduce an index correction.

134. To Measure a Precise Vertical Angle. The instrument should be leveled precisely, by using the telescope level. A method must be chosen that will obtain an average of several readings of the vernier. Reading the vernier after each of several pointings will not accomplish the result, for the reading will probably be the same each time. The desired result is best accomplished by utilizing the **stadia cross hairs.** Most instruments have supplementary horizontal cross hairs, one above and one below the center hair. They are used for stadia measurements described in another chapter. Read the vertical angles obtained by aiming the three cross hairs successively at the point both direct and reversed. Use the average of the six values obtained.

135. To Use the Transit at Close Quarters. In aligning machinery it is often necessary to use short sights of varying lengths. This requires large movements of

the objective along its slide in order to focus. Any misalignment of the slide is thus magnified. Observations direct and reversed will eliminate the error introduced (see Fig. 27).

136. The Care of the Instrument. Complete directions for instrument care are beyond the scope of this text. The following rules plus a recognition of the delicacy of the instrument will usually prevent damage. The most important rule is to prevent falls. A fall will always result in the need for extensive repairs or will destroy the instrument entirely. The rules apply both to the transit and to the level.

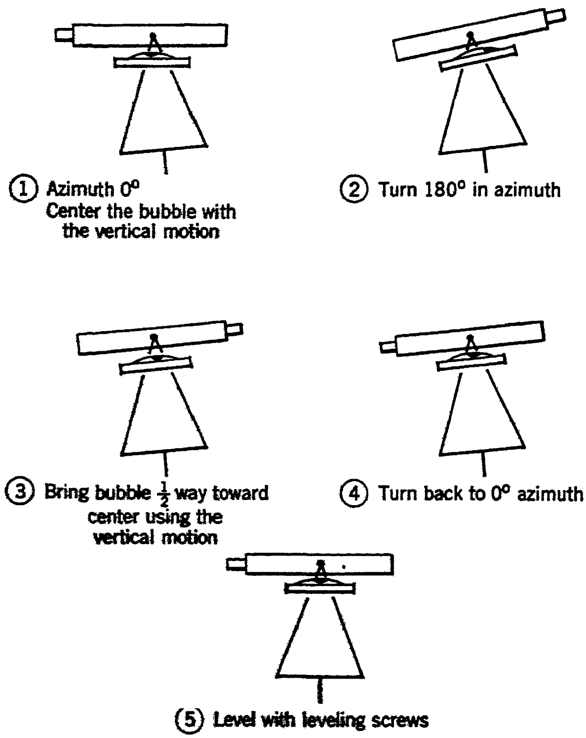


FIG. 25.—Leveling an instrument by means of the telescope level.

1. **Handle the instrument by the base** when not on the tripod. This prevents deflecting the more delicate parts.

2. **Never stand the tripod on a smooth surface.** The legs may slip outward.

3. **Always stand the tripod up carefully.** The legs must be wide and firm even when the setup is not to be used for observations. The wind or a slight touch may knock it over.

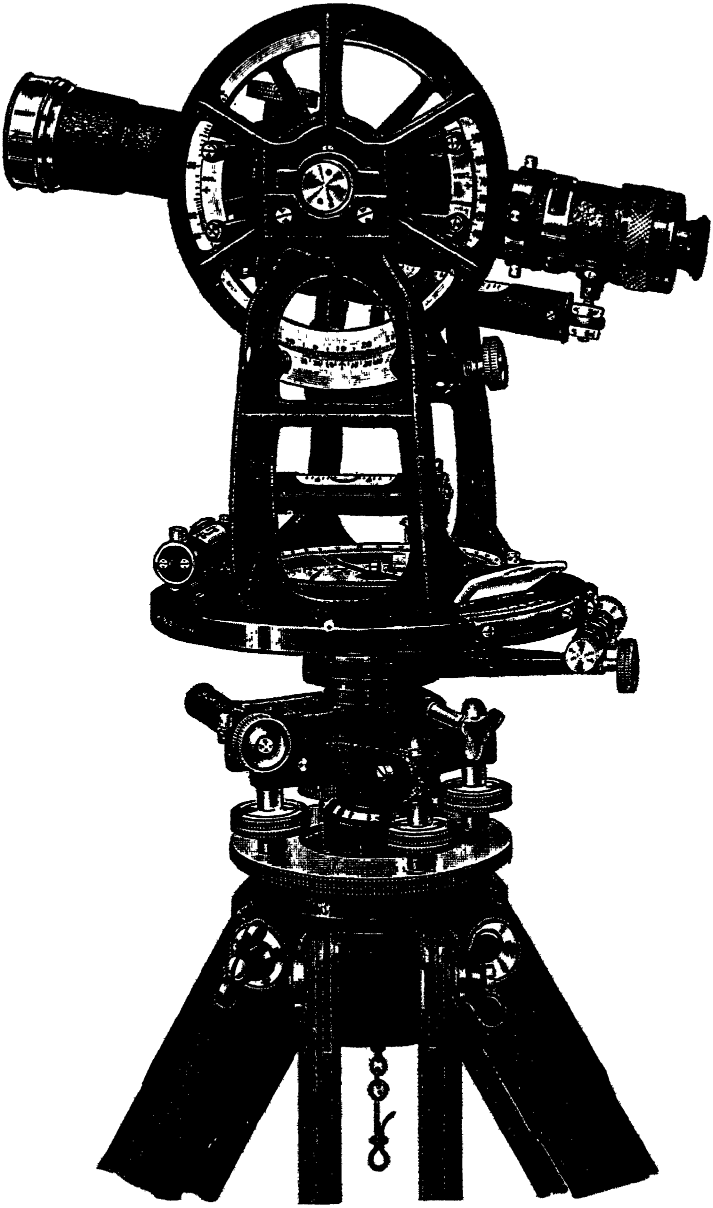


FIG. 26.—A Keuffel & Esser engineer's transit completely equipped. It has a 6¼-inch circle, a telescope level, a full vertical circle, and stadia reduction circle. (*Keuffel & Esser Co.*)

4. **Never leave the instrument unattended** unless special precautions are made for its protection.

5. **Never subject the instrument to vibration,** which ruins the adjustments. Most instrument cases have large rubber feet, which absorb vibration if the rest of the case is free from contacts.

6. **Never force the instrument.** If the telescope or alidade do not turn easily, do not continue to use the instrument. Such use might damage a bearing.

7. **Keep the instrument in its case.** This usually guarantees protection.

8. **Place it in the case so that the only contact is with the base.** Keep all three transit clamps tight. This reduces chances for vibration. Some cases have felt-covered contact points, which are safe.

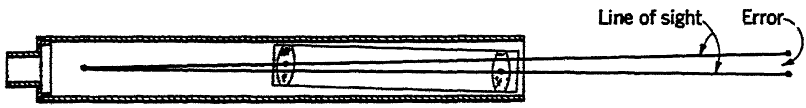


FIG. 27.—Error caused by misalignment of the objective slide.

9. **Keep the instrument free from dust and rapid temperature changes.** Dust ruins the finish and the bearings. Temperature ranges introduce moisture into the telescope tube. The moisture will fog the telescope, and the telescope must be dismantled to remove it.

10. **If the instrument is wet let it dry.** Do not dry it, for this ruins the finish and smears the glass and graduations.

PROBLEMS

Complete the field notes and make the station adjustments for the following sets of data from horizon closures. The method of 3 D.R. was used.

1

°	′	″	
		A	*B*
0	0	00	$\overline{45}$
92	13	30	
193	21	15	30
0	0	00	15
156	47	45	
220	46	15	30
0	0	00	$\overline{30}$
110	58	30	
305	52		

2

°	′	″	
		A	*B*
0	0	00	30
117	58	15	$\overline{45}$
347	47	00	$\overline{45}$
0	0	00	15
174	19	30	45
325	57	15	$\overline{30}$
0	0	00	15
67	43	00	$\overline{45}$
46	16	15	$\overline{45}$

3

°	′	″	
		A	B
0	0	00	30
177	45	30	
346	31	15	45
0	0	00	$\overline{30}$
81	57	00	
131	43	30	15
0	0	00	$\overline{45}$
72	29	00	
74	54	15	30
0	0	00	15
27	48	30	
166	50	15	0

4

°	′	″	
		A	B
0	0	00	$\overline{45}$
83	54	15	45
143	27	30	30
0	0	00	30
23	02	30	30
138	14	15	45
0	0	00	15
18	09	30	60
108	59	0	30
0	0	00	$\overline{30}$
234	52	45	75
329	19	15	$\overline{45}$

CHAPTER VI

ADJUSTMENT OF TRANSIT

137. The Adjustment of Instruments. The importance of instrument adjustment cannot be overemphasized. While the errors resulting from lack of adjustment can be eliminated by the principle of reversal in the operation of the instrument, the time consumed for this procedure usually limits it to primary measurements. In locating topographical features, establishing a large number of gauge points in a jig, or in fact, working the great bulk of instrument operations in the field or shop, the time necessary for reversals prohibits their use.

138. The instrumentman must be trained so thoroughly in the theory and methods of instrument adjustment that he can be relied upon to perform the five following functions without fail:

1. He must recognize the operations that depend on the accuracy of instrument adjustment.
2. He must be able to test the instrument in the course of the work.
3. He must be able to adjust it with the minimum of delay.
4. He must be able to judge when the accuracy of measurement requires reversal even when the instrument is in adjustment.
5. When necessary he must be able to operate the instrument so that the reversal principles will neutralize instrument errors.

139. Method of Presentation. To simplify the text without omitting details, schematic sketches are used to demonstrate the adjustment operations. Beside each screw shown in the sketches is an arrow that indicates the direction of movement of the side of the screw nearest the observer. The numbers in circles show the order of procedure. The fractions beside the arrows give very approximately the fractions of a turn that should be applied to the screws.

140. The sketches show typical adjustment parts. There are slight variations from instrument to instrument, but the reader will have no difficulty in discovering how to handle types not shown.

141. Order of Adjustment. Obviously, certain adjustments will upset others. It is necessary therefore to make adjustments according to the order in which they are given in the text.

142. Final Adjustment. Opposing screws or nuts are used on most adjustable parts. Forcing them in the wrong direction will strip the

threads. However, when the final adjustment is complete, the screws must be firm. The last increment of adjustment must therefore be made by tightening one screw of the pair.

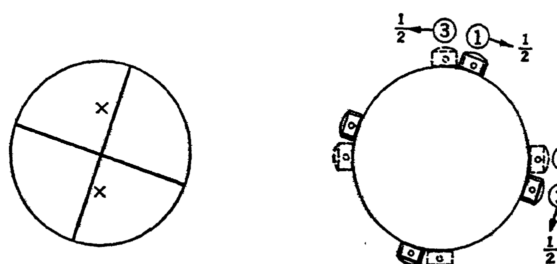
143. The Neutralization of the Residual Errors of Adjustment. After each adjustment there is described, under the heading Neutralization, the field procedure that will neutralize errors caused by lack of the adjustment. When highly accurate results are required, the instrument must be operated so that any residual errors are neutralized. When less accurate results are required and it becomes apparent that the instrument is not in adjustment, these methods can be employed until adjustment can be accomplished.

ADJUSTMENT A

144. Object. To make vertical cross hair lie in a plane perpendicular to horizontal axis.

Test. Point on some well-defined point. Rotate the telescope slightly about the horizontal axis, using the vertical tangent screw. The point should remain on the cross hair.

Adjustment. Loosen two adjacent cross-hair adjusting screws, and by moving the screws rotate the cross hairs in the desired direction. Tighten the screws (see Fig. 1).



Appearance of field in both erecting and inverting instruments

As the telescope is rotated about the horizontal axis the point x apparently moves along the line connecting the two positions shown

Rotate the cross-hairs counterclockwise until the point x follows the vertical cross-hair

FIG. 1.—Transit Adjustment A.

Repeat test.

Neutralization. Use only that part of the vertical hair which is close to the horizontal cross hair.

Geometry. A lens forms an image that is rotated 180 deg around the lens axis with respect to the object. Direction of rotation therefore is not changed by a lens as it is by a mirror.

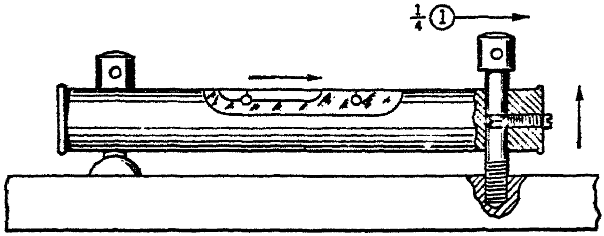


FIG. 2.—Transit Adjustment 1. The adjustment of the plate levels. Continue until the bubble moves halfway back.

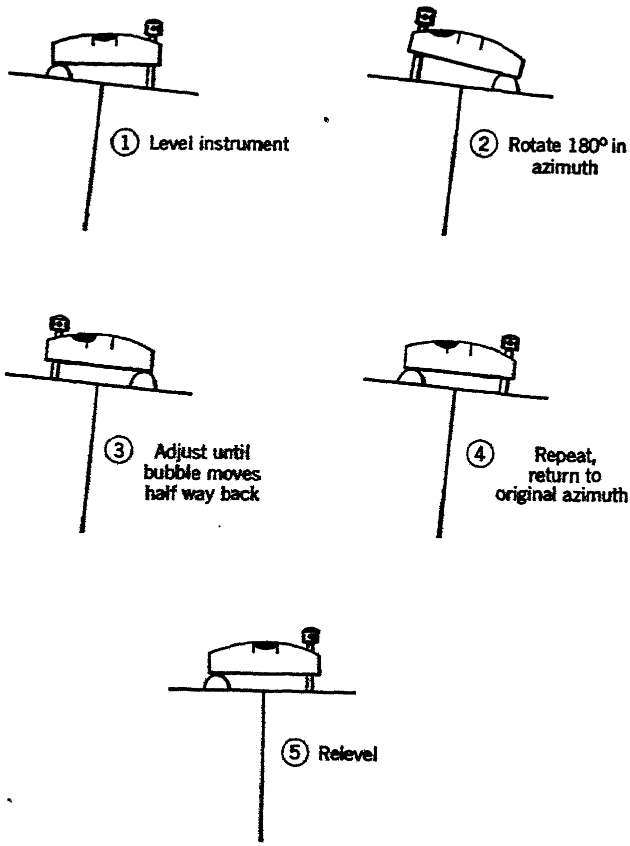


FIG. 3.—Principles of adjustment of plate bubbles.

ADJUSTMENT 1

145. Object. To make plate bubbles center when vertical axis is vertical.

Test. Level instrument. Rotate 180 deg in azimuth. The bubbles should remain centered.

Adjustment. Assume bubble moves away from adjustment end. Follow indications on sketch until the bubble moves halfway back (Fig. 2).

Repeat test.

Neutralization. Level instrument. Rotate 180 deg in azimuth. If bubbles fail to center, bring them halfway back with leveling screws.

Geometry. Figure 3 shows that the error of adjustment creates an error of setup. When the instrument is turned 180 deg, the error of adjustment combines with the error of setup to move the bubble twice the amount caused by the error of adjustment alone.

ADJUSTMENT 2

146. Object. To make line of sight perpendicular to horizontal axis.

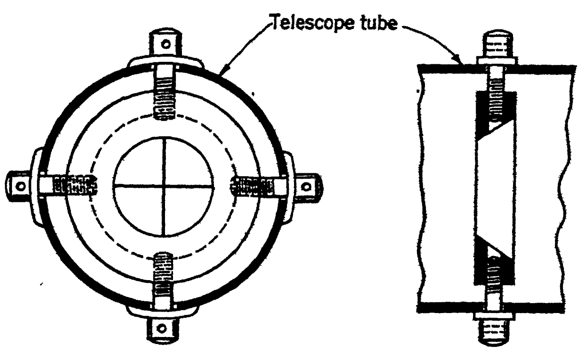


FIG. 4.—Cross hairs and reticle. The four adjusting screws are in tension.

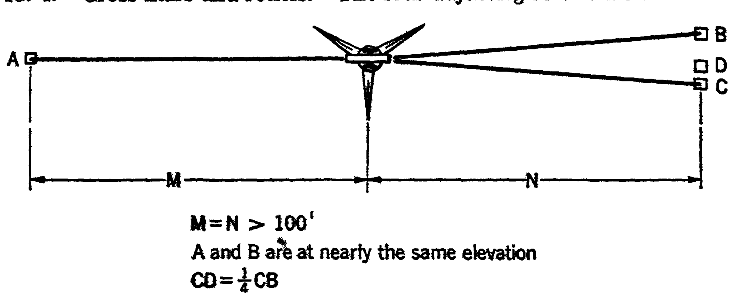


FIG. 5.—Transit Adjustment 2.

Test. Set up near the center of a level stretch. Point on a well-defined mark at A 100 feet or more distant. Transit telescope, and set B on line, at nearly the same elevation and distance as A. Traverse,

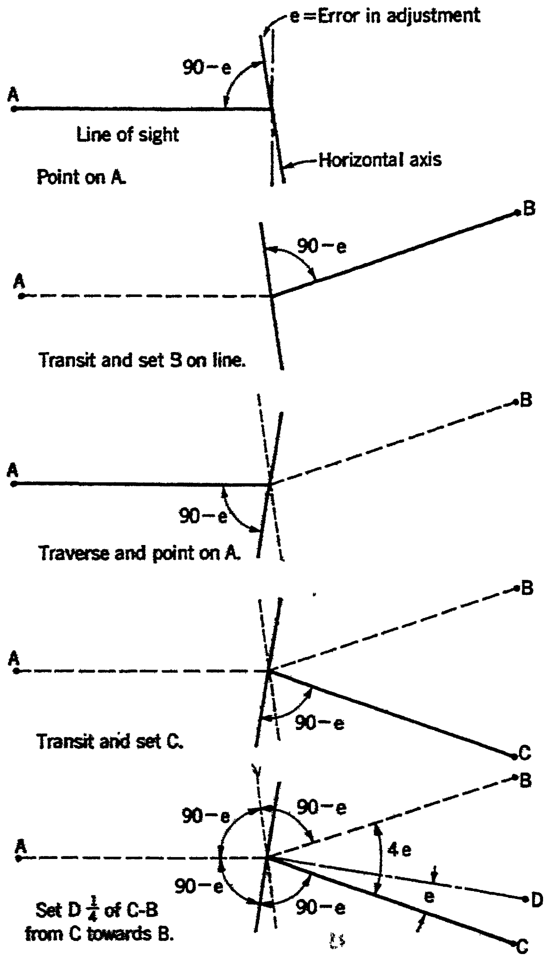


FIG. 6.—Principles of adjustment of line of sight.

and point on A. Transit, and the line of sight should fall on B (see Fig. 5).

Adjustment. Assume line of sight falls south of point. Set point C on line beside B. Follow indications on sketches until cross hairs appear to move to D, one-fourth of the way from C toward B (see Figs. 4, 8).

Repeat test.

Neutralization. Point on A. Transit, and set B. Traverse, and point on A. Transit, and set C. Set a line point halfway from C to B. This is called **double centering.**

Geometry. Since, when the cross hairs are adjusted, the line of sight pivots about the center of the objective, to move the line of sight toward

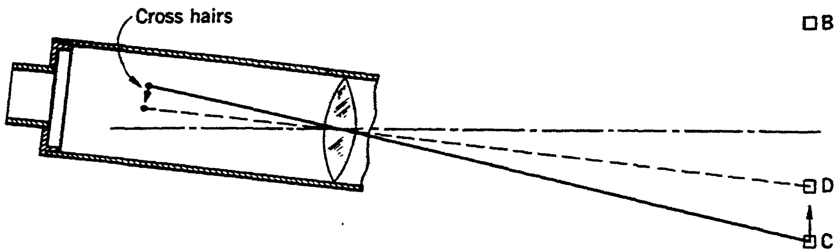


Fig. 7.—Direction to move cross hairs. When D is north of C, cross hairs must be moved south physically.

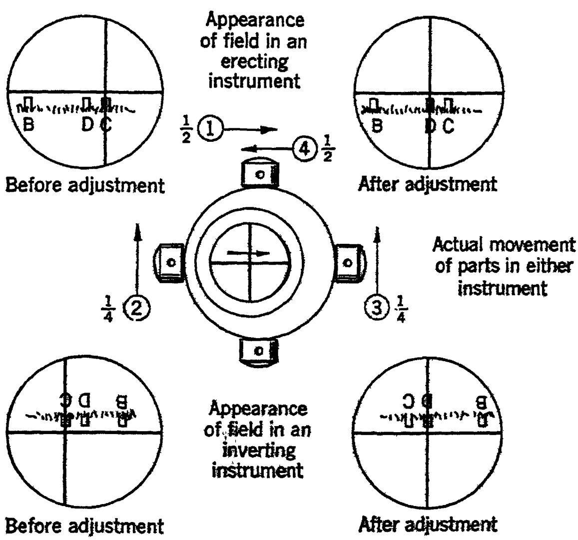


Fig. 8.—Transit Adjustment 2. The appearance of the field of view after the test.

the north the cross hairs must be physically moved south (see Fig. 7). Therefore in adjusting an erecting instrument the cross hairs must be moved apparently in the wrong direction. In adjusting an inverting instrument, since in the inverted view north and south are apparently interchanged, the adjustment is made in apparently the right direction.

Before the cross-hair ring can be moved sideways an upper or lower adjusting screw must be loosened.

The procedure outlined collects four times the error in adjustment between B and C, as shown in Fig. 6. Hence D is set one-fourth of the distance from C toward B.

ADJUSTMENT 3

147. Object. To make horizontal axis perpendicular to vertical axis.

Test. Set up near a high, well-defined point such as a church steeple. Point on the high point A. Lower the telescope, and set point B on the

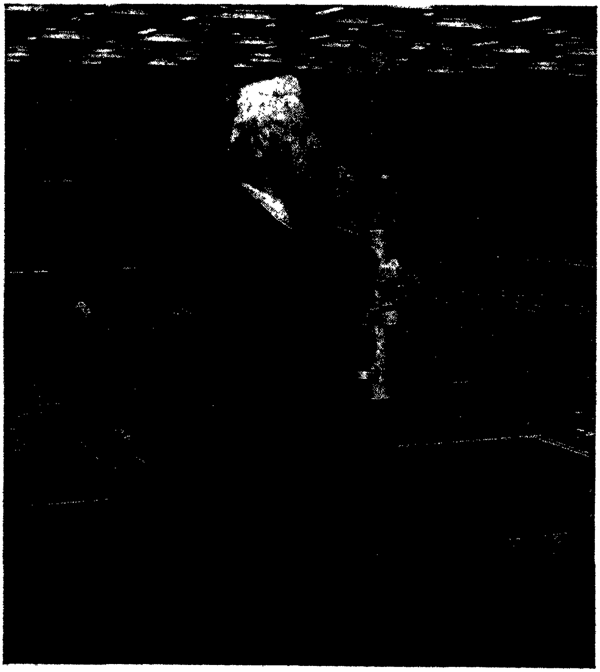


FIG. 9.—Checking the third adjustment at the Renton plant of the Boeing Aircraft Co. (*Boeing Aircraft Co.*)

ground in line about 20 feet in front of the instrument. Transit and traverse, and point on B. Raise the telescope, and the line of sight should fall on the high point.

Adjustment. Assume that line of sight falls on the opposite side of high point from the adjustable end of horizontal axis. Follow indications on sketch (Fig. 10) until the line of sight moves one-fourth to one-half of the way back. On most transits, as shown in sketch, the adjusting screws also control the bearing pressure. The pressure should prevent the telescope from plunging under its own weight but not create any noticeable friction.

Repeat test.

Neutralization. Repeat any procedure with the telescope reversed, and use the average of the results.

Geometry. (See Fig. 11.) The line of sight is first directed at A. The left end of the horizontal axis is high; therefore, when the line of sight is moved downward, it also moves to the left, generating a plane that inclines from the vertical an amount equal to the error in the adjustment of the horizontal axis, viz., angle E_1. Point B is set accordingly.

The transit is now reversed, making the right end of the horizontal axis high. The line of sight is now directed at B and raised to C, level with A. As it is raised, it moves to the left, generating another plane

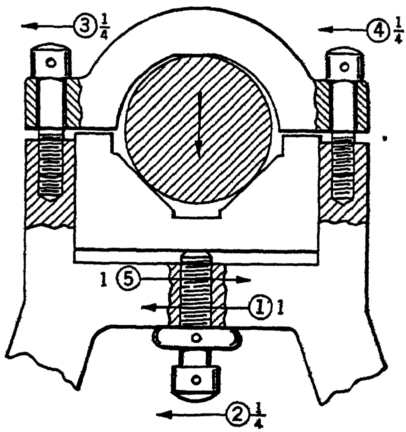


FIG. 10.—Transit Adjustment 3. Procedure for lowering the adjustable end of the horizontal axis. On most transits, as shown here, the adjusting screws also control the bearing pressure. Play, or excessive friction in the bearings, must be avoided.

inclined to the vertical (on the opposite side) an amount equal to the error in the adjustment of the horizontal axis, viz., E_2.

The problem now arises: Toward what point should the line of sight be directed by adjusting the horizontal axis to eliminate the error?

When the horizontal axis is being adjusted, the plane that the line of sight normally generates is rotated about the line OG, which is perpendicular to the vertical axis. The plane should be rotated until it is vertical, i.e., rotated through an angle $E_3 = E_2 = E_1$. When so rotated, the line of sight will point at D and D' in the vertical plane through OG.

In order to estimate the distance CD, its relation to CA must be determined.

From the figure;

$$\frac{CD}{CV} = \frac{C'D'}{C'V'} = \frac{D'G}{V'B} = \frac{\alpha}{\alpha + \beta} \qquad \text{since } E_3 = E_2$$

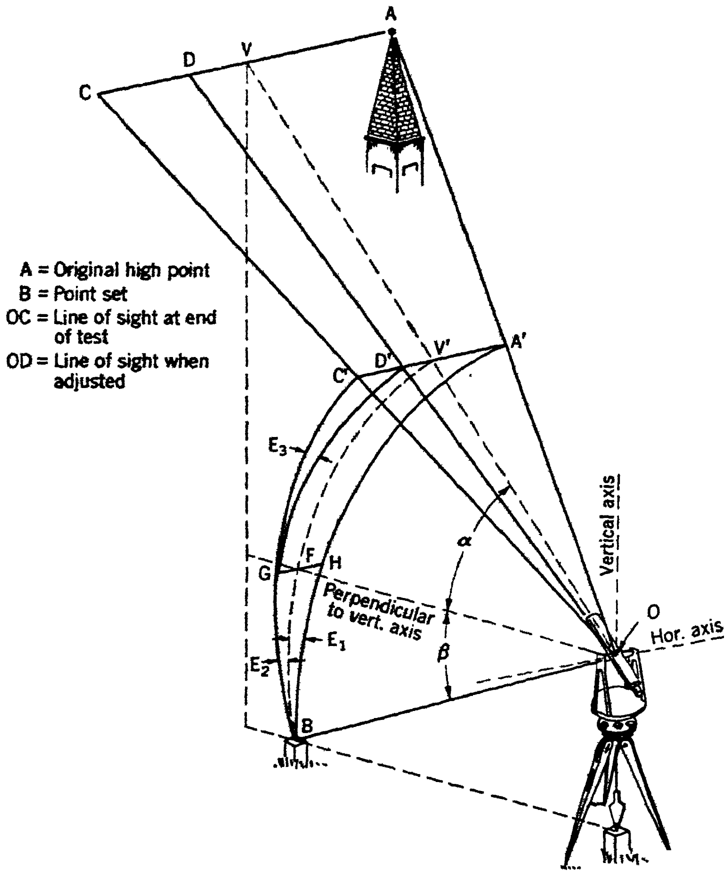


FIG. 11.—The geometric concepts of the third transit adjustment.

whence

$$CD = \frac{\alpha}{\alpha + \beta} CV$$

but

$$CV = VA = \frac{CA}{2} \qquad \text{since } E_2 = E_1$$

By substitution,

$$CD = \frac{\alpha}{\alpha + \beta} \frac{CA}{2}$$

If point B should be at the same elevation as the transit,

$$\beta = 0, \qquad CD = \frac{CA}{2}$$

If

$$\beta = \alpha, \qquad CD = \frac{CA}{4}$$

Therefore, if

$$\alpha > \beta > 0$$

then

$$\frac{CA}{4} < CD < \frac{CA}{2}$$

As it is unlikely that β is less than zero or greater than α, the statement can safely be made that the line of sight shall be moved a distance CD, which is between one-fourth to one-half the total distance CA.

It should be noted that, while the term **vertical** is used for simplicity, the adjustment is independent of the direction of gravity. In every case for vertical can be substituted **a plane containing the vertical axis.** It is therefore unnecessary to level the instrument carefully or in fact at all.

ADJUSTMENT 4

148. Object. To make the telescope level bubble center when the line of sight is horizontal. This is often known as the **peg adjustment.**

Test. Set stakes (or pegs) in line as shown in Fig. 12. Set up at C, and take rod readings on B and D, centering the bubble in the telescope level before each reading. Set up at A, and read rod on B. The assumed rod readings are shown in the figure.

Do the following arithmetic:

$$\begin{array}{rc}
2.981 & D_1 \\
\underline{-4.067} & \underline{-B_1} \\
-1.086 & \Delta \\
\underline{+7.438} & \underline{+B_2} \\
+6.352 & D_2
\end{array}$$

Read rod on D. It should read 6.352 if in adjustment.

Adjustment. Assume it reads 6.473.

Do the following arithmetic:

$$\begin{array}{rc}
6.352 & D_2 \\
\underline{-6.473} & \underline{-D_3} \\
-0.121 & C \\
\underline{\times\ \ 0.1} & \underline{\times 0.1} \\
-0.012 & d \\
\underline{+6.352} & \underline{+D_2} \\
6.340 & D_4
\end{array}$$

Set target at 6.340. D_4

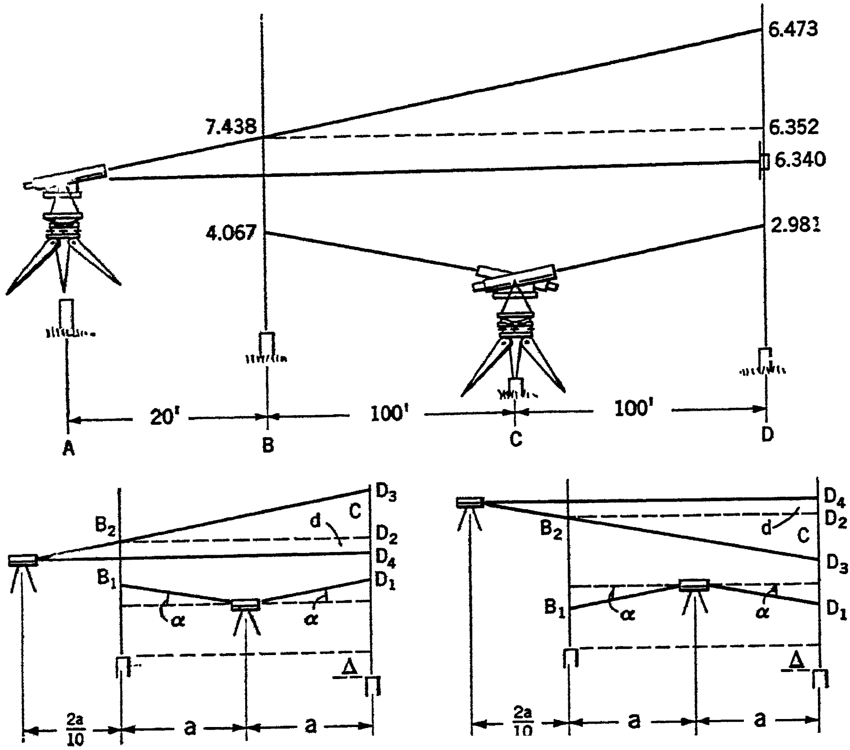


FIG. 12.—The peg adjustment.

Using the vertical tangent screw, point on target. Follow the indications on the sketch (Fig. 13) until the bubble moves to center.

Repeat test.

Neutralization. Set up the instrument at equal distances from the point observed.

Geometry (see Fig. 12). No matter how the instrument is adjusted at the start, the line of sight will always make the same angle (α) with the horizontal when the bubble is centered. By congruent tri-

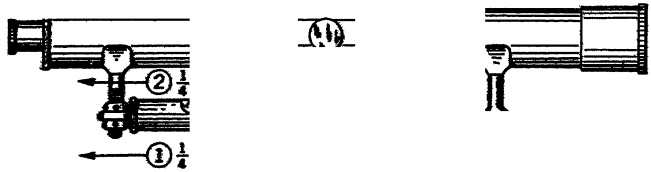


FIG. 13.—Transit Adjustment 4. Adjustment of the telescope level. After pointing on the target, adjust until the bubble moves all the way to center.

angles, B_1 and D_1 are at the same elevation, and

$$\Delta = D_1 - B_1$$

where Δ is the quantity that must be added to any reading on B to obtain a reading at the same elevation on D. When the reading B_2 is obtained on B, the reading D_2 should be obtained on D if the instrument is in adjustment.

$$D_2 = \Delta + B_2 \qquad \text{by definition of } \Delta$$

and

$$C = D_2 - D_3 \qquad \text{a correction}$$

but

$$d = \frac{C}{10} \qquad \text{by similar triangles}$$

and

$$D_4 = D_2 + d$$

where D_4 is a reading at the same elevation as the transit.

ADJUSTMENT B

149. Object. To make vertical circle indicate zero when line of sight is perpendicular to vertical axis.

Test. Level instrument, using the telescope bubble (see Art. 130). Using lower motion, turn the instrument until the telescope is on line with a pair of opposite leveling screws. Center telescope bubble, using vertical motion.

The vertical circle should now read zero.

Adjustment. Loosen nuts behind vernier. Tap vernier into position. Tighten nuts (Fig. 14).

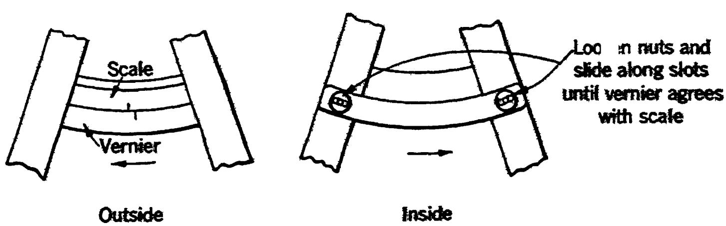


FIG. 14.—Transit Adjustment B. The adjustment of the vertical vernier.

Neutralization. Read vertical angles direct and reversed, and use the average.

Geometry. The vertical axis has been made vertical by the method of leveling. The line of sight is horizontal as the telescope bubble is centered. Therefore the line of sight and the vertical axis are perpendicular, and the vernier should read zero.

PROBLEMS

1. The geometric relationship between an object and its image formed by a lens is the same as would be the case if a pinhole were substituted for the center of the objective. Draw a sketch showing that a lens in forming the image rotates the object 180 deg around the lens axis.

2. Show, using sketches, why the plate levels are adjusted so that the bubble moves only halfway back toward the center.

3. Write out Adjustment 1 complete with sketches, arrows, etc., assuming that at the end of the test the bubble moves toward the adjustment end.

4. Draw sketches of the field of view as seen by an observer when, at the end of the test in Adjustment 2, the line of sight actually falls to the left of point B.

5. Write out Adjustment 2 complete with sketches showing arrows, etc., for conditions in Prob. 4.

6. Assume that at the end of the test in Adjustment 3 the line of sight apparently missed the high point by the distance CA. If the vertical angles were $+40$ and -20 deg, respectively, how far should the line of sight be moved by adjustment?

7. Write out Adjustment 3 complete with sketches, arrows, etc., assuming that at the end of the test the line of sight falls on the same side of the high point as the adjustment end.

8–11. Compute the target setting for Adjustment 4 if the data are the following:

	Readings at C		Readings at A	
	Rod B	Rod D	Rod B	Rod D
8	2.341	1.268	4.632	3.548
9	2.341	1.268	4.632	3.583
10	1.246	4.457	5.289	8.532
11	1.246	4.457	5.289	8.484

CHAPTER VII

TRAVERSES

150. Traverses. A traverse consists of a continuous series of lines called **courses** running between a series of points called traverse stations. The lengths of the lines and the angles between them are measured. Traverses can be either open or closed. Open traverses end without closure. They cannot be properly checked and therefore are not recommended. Closed traverses are of two kinds, loop traverses and connecting traverses. Loop traverses close on themselves, and connecting traverses begin at a known direction and position and end at another known position and direction. Thus both the angles and the measured lengths in a closed traverse may be checked.

151. Use of Traverses. Traverses, like triangulation surveys, are used to find the accurate positions of a relatively few marked points called stations. From this system of stations, many less precise measurements can be made to features to be mapped or located, without accumulating accidental errors. Traverses thus usually serve as control surveys. When plans for construction are drawn, the stations can again be used as beginning points from which to lay out work. Traverses are cheaper and more effective than triangulation in small areas or where many obstacles interfere with sight lines.

152. Thus, when new construction of any kind is desired, a system of traverse stations in the area involved must be established and surveyed at the outset. Efforts to avoid this operation because of ignorance or inertia are usually costly, retard the work, and often cause serious revision of plans.

153. Field Work. The positions of the traverse stations are chosen so that they are as near as possible to the objects to be located without unduly increasing the work of measuring the traverse. They are usually marked by stakes with tacks or by stone or concrete monuments set nearly flush with the ground, with a precise point marked on the top by a chiseled cross, drill hole, or special bronze tablet.

154. The angle and length measurements are made as described elsewhere. Signals must be placed at the stations so that the rear tapeman can align the taping and for angle measurement. Many types of signals

have been devised. Usually a range pole stuck in the ground is used for taping, and a range pole held carefully balanced on the point is used for measuring angles. When the courses are short, a plumb bob is held over the point or a pencil is balanced on it for angle measurements (see Fig. 1). Considerable time can be saved by rigging a device to support one of these signals in place so that a man is not required to hold it.

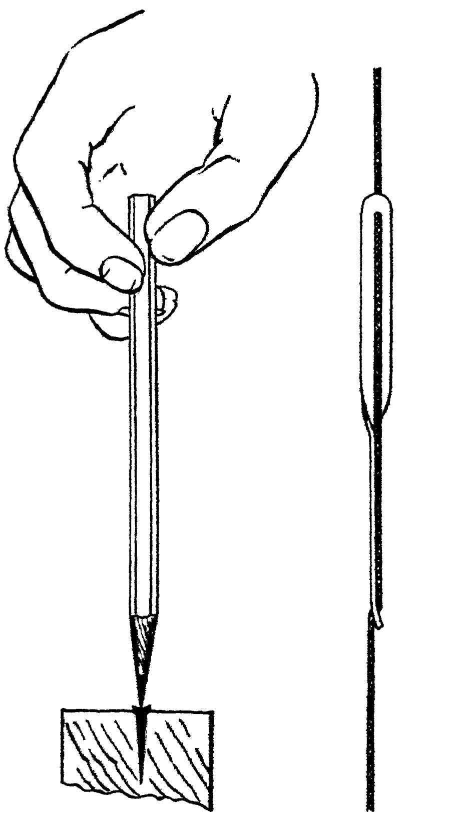


FIG. 1.—Targets for transit observation.

155. Forward Direction. For purposes of consistency it is necessary to assume which is forward and which is backward for any traverse. The order in which it is measured is usually called the **forward direction.** Loop traverses should be measured counterclockwise around the loop.

156. Direction of Angle Measurement. The angles of a traverse should be measured clockwise from the backward direction to the forward direction. This is the most rapid field method and the least likely to introduce blunders. Some engineers recommend measuring deflection angles. A deflection angle is the angle between the forward prolongation of the back course and the forward course (see Fig. 2). It can also be defined as the change of direction of the traverse at a station. Unless

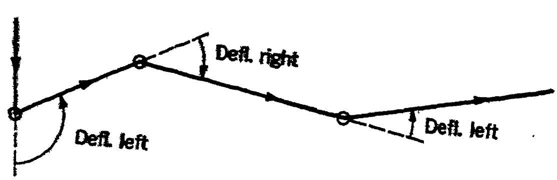


FIG. 2.—Deflection angles.

the directions of the deflection angles left or right are properly recorded, a blunder will result. Deflection angles are therefore not covered in this text, although they slightly reduce computation.

STEPS IN THE COMPUTATION OF A TRAVERSE

157. Usually it is necessary to reduce the traverse field data to the form of the rectangular coordinates of the stations. This is accomplished by the type of computation described in the following paragraphs.

158. As a guide to computation a sketch of the traverse should be drawn approximately to scale, showing the names of each of the traverse stations.

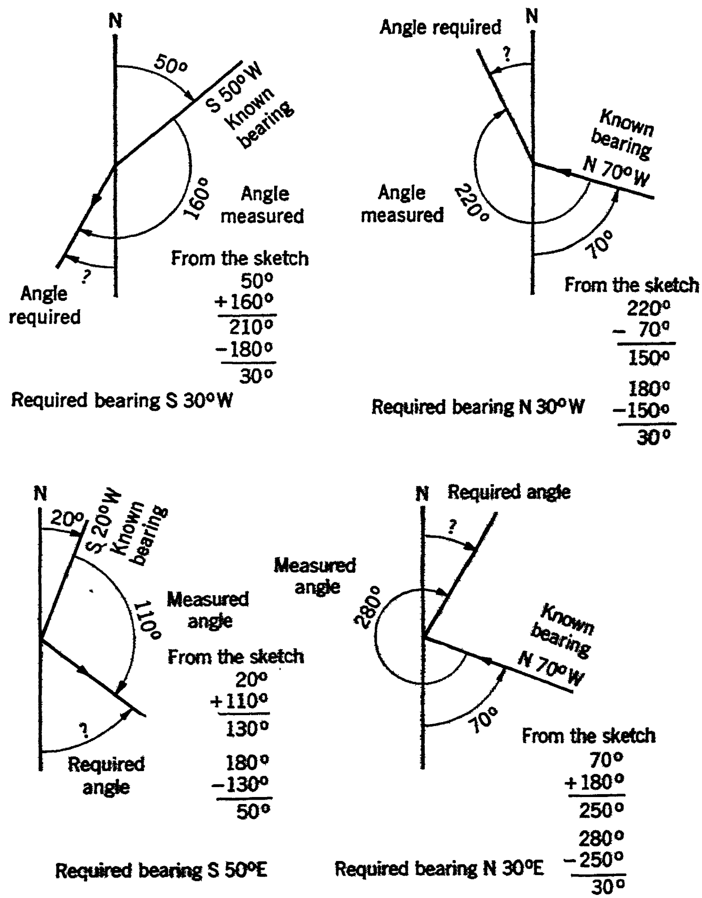
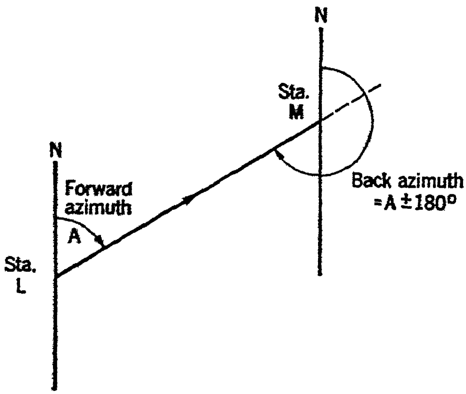


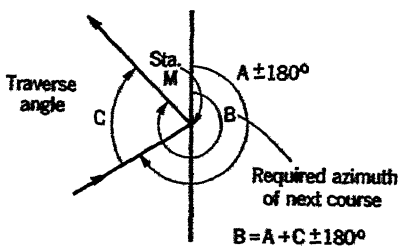
FIG. 3.—Typical sketches for computation of bearings.

159. Computation of Direction. One of the first operations in computing a traverse consists in computing the directions of successive courses by applying a traverse angle to the direction of one course to obtain the direction of the following course. When bearings are used to express direction, the best method of accomplishing this is to draw a sketch for each station showing the meridian and the two courses involved (see Fig. 3). The required arithmetic will then be evident. Sketches may also be relied on when azimuths are used, but if the angles are measured as recommended, considerable time may be saved by using a rule for computing direction.



160. Azimuth Rule (see Fig. 4).

$B = A + C \pm 180°$
B = azimuth of the next course
A = azimuth of the previous course
C = traverse angle



Rule: Add the traverse angle to the previous azimuth and add or subtract 180°

FIG. 4.—The azimuth rule.

It is evident that $A \pm 180$ deg is the back azimuth of the previous course. C can then be added, for it is measured in such a way that it expresses the increase in azimuth from the back azimuth of the previous course to the forward azimuth of the next course. It may be necessary sometimes to add or subtract 360 deg to avoid minus angles or angles that are over 360 deg.

161. Examples of Traverse Computation. The computation of a loop traverse and of a connecting traverse are here given in detail.

162. Loop Traverse. Figure 5 illustrates a loop traverse. In order to simplify it and to illustrate the procedure properly, the precision, and hence the accuracy, is very low. The data given are the data obtained in the field. The required steps are listed in order.

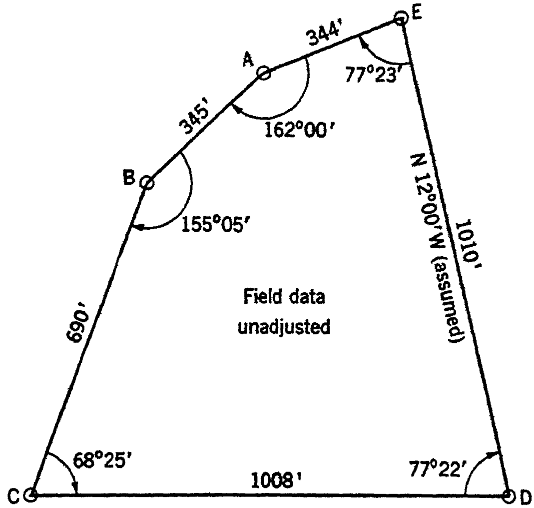


FIG. 5.—Example of a loop traverse showing unadjusted field data.

1. **Compute the angular error.** The sum of the angles should be

$$(n - 2)180° = 540°$$

A	162°00′
B	155°05′
C	68°25′
D	77°22′
E	77°23′
Sum	540°15′
	−540°00′
Total angular error	15′

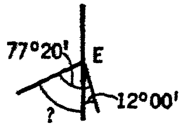
Error per angle, 15′ ÷ 5 = 3′

Assume that an angular error of 5 minutes per angle is allowed. The angular measurement is thus acceptable.

2. **Adjust the angles.** Give the same correction to each angle, as the chance for error is the same.

A	162°00′ − 3′ =	161°57′
B	155°05′ − 3′ =	155°02′
C	165°25′ − 3′ =	68°22′
D	77°22′ − 3′ =	77°19′
E	77°23′ − 3′ =	77°20′
Sum	=	540°00′ Check

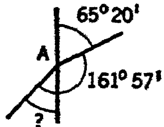
3. **Compute bearings.** Starting with an assumed or known bearing (in this case *D-E* = N 12°00′ W), compute the bearings by applying the corrected angles successively.



D-E N 12°00′ W

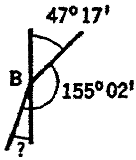
E-A S 65°20′ W

$$\begin{array}{r} 77 - 20 \\ -\ \underline{12 - 00} \\ 65 - 20 \end{array}$$



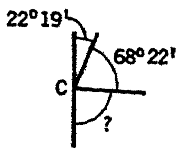
A-B S 47°17′ W

$$\begin{array}{r} 65 - 20 \\ +\underline{161 - 57} \\ 227 - 17 \\ -\underline{180} \\ 47 - 17 \end{array}$$



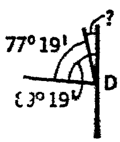
B-C S 22°19′ W

$$\begin{array}{r} 47 - 17 \\ +\underline{155 - 02} \\ 202 - 19 \\ -\underline{180} \\ 22 - 19 \end{array}$$



C-D S 89°19′ E

$$\begin{array}{r} 22 - 19 \\ +\ \underline{68 - 22} \\ -\ 90 - 41 \\ \underline{179 - 60} \\ 89 - 19 \end{array}$$



D-E N 12°00′ W Check

$$\begin{array}{r} 89 - 19 \\ -\ \underline{77 - 19} \\ 12 - 00 \end{array}$$

4. Compute the latitudes and departures.

Latitude = Δy = length multiplied by cosine of bearing
N = plus
S = minus
Departure = Δx = length multiplied by sine of bearing
E = plus
W = minus

If a computing machine is available, natural functions should be used. The form shown here is for logarithmic computation. The log of the length is placed at the middle of the column for each course, the log cos bearing is placed directly above it, and the log sin bearing is placed below it. The two upper logs are added to obtain the log of the latitude, and the two lower logs are added to obtain the log of the departure.

5. **Compute the error.** Since the traverse begins and ends at the same point, the sum of the latitudes and the sum of the departures should both be zero. By adding the columns the errors can be found. The error in latitude is -40; the error in departure is -30. The **total error** is evidently the square root of the sum of the squares of these values.

$$\text{Total error} = \sqrt{(-40)^2 + (-30)^2} = 50$$

Form for the Computation of Coordinates

Sta.	Corrected bearings	log	Unadjusted		Corrections		Adjusted	
	Lengths		Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
							Coord.	
A	S 47°17′ W	2.36929						
		9.83147						
	345	2.53782	− 234	− 253	+ 4	+ 3	− 230	− 250
		9.86612						
B		2.40394					+ 630	+ 256
B	S 22°19′ W	2.80504						
		9.96619						
	690	2.83885	− 638	− 262	+ 8	+ 6	− 630	− 256
		9.57947						
C		2.41832					0	0
C	S 89°19′ E	1.07996						
		8.07650						
	1008	3.00346	− 12	+1,008	+12	+ 9	0	+1,017
		9.99997						
D		3.00343					0	+1,017
D	N 12°00′ W	2.99472						
		9.99040						
	1010	3.00432	+ 988	− 210	+12	+ 9	+1,000	− 201
		9.31788						
E		2.32220					+1,000	+ 816
E	S 65°20′ W	2.15705						
		9.62049						
	344	2.53656	− 144	− 313	+ 4	+ 3	− 140	− 310
		9.95844						
A		2.49500					+ 860	+ 506
			+ 988	+1,008	+40	+30		
			−1,028	−1,038				
Sum	3397		− 40	− 30				

6. **Compute the measure of accuracy or simply the accuracy.** This is the ratio of the total error to the total length of the survey. The sum of the lengths of the courses is 3,397; hence

$$\text{Accuracy} = 50:3{,}397 = 1:68$$

The accuracy of the usual transit traverse is 1:3,000. If the ratio is larger, a blunder probably exists and the survey is rejected. The survey used in the example would of course be rejected but is used for reasons explained previously.

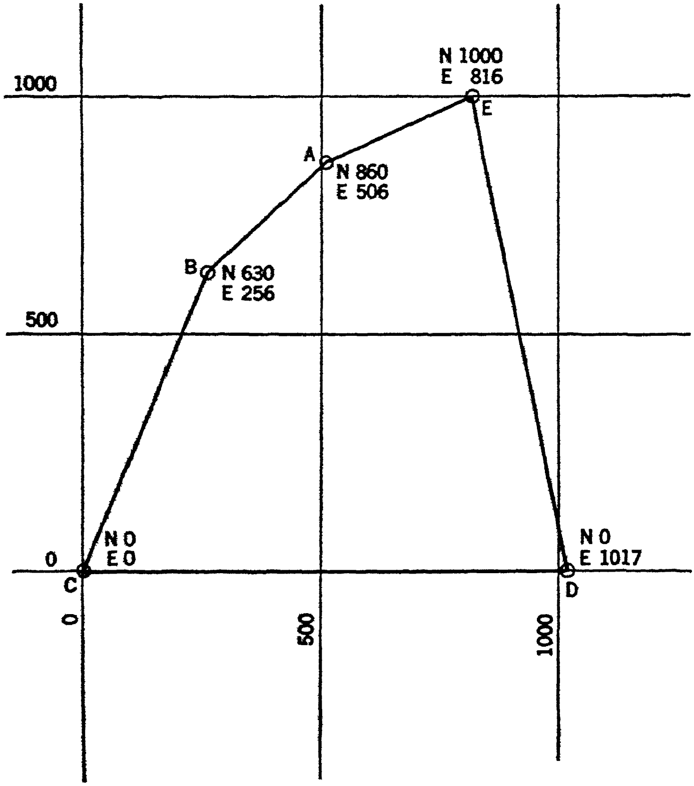


FIG. 6.—Adjusted loop traverse plotted by coordinates.

7. Compute the corrections to latitudes and departures. These are arranged to counterbalance the errors and are proportional to the lengths of the courses. These are computed by slide rule. The formula is as follows:

$$\text{Cor.} = \frac{C}{L} \cdot S$$

where Cor. = correction to latitude (or departure)

C = total error in latitudes (or departures) with the sign changed

L = total length of the survey

S = length of the particular course

The results from the slide rule are placed directly in the form. The total correction must be equal to the error with the sign changed. Owing to cutting off decimals it is sometimes necessary to change one or two corrections to create this relationship.

	Cor. to Latitudes	Cor. to Departures
AB	$\frac{40}{3{,}397} \times 345 = 4$	$\frac{30}{3{,}397} \times 345 = 3$
BC	$\frac{40}{3{,}397} \times 690 = 8$	$\frac{30}{3{,}397} \times 690 = 6$
CD	$\frac{40}{3{,}397} \times 1{,}008 = 12$	$\frac{30}{3{,}397} \times 1{,}008 = 9$
DE	$\frac{40}{3{,}397} \times 1{,}010 = 12$	$\frac{30}{3{,}397} \times 1{,}010 = 9$
EA	$\frac{40}{3{,}397} \times 344 = 4$	$\frac{30}{3{,}397} \times 344 = 3$
	Total $= \overline{40}$	Total $= \overline{30}$

8. **Compute the adjusted latitudes and departures.** The signs of the corrections are, of course, opposite to the sign of the error. Add the corrections algebraically to the unadjusted latitudes and departures.

9. **Compute the coordinates.** Choose coordinates such that all coordinates will be plus. In the example, point *D*, the most southerly point, is given a *y*, or north, coordinate of zero, and the point *C*, the most westerly point, is given an *x*, or east,

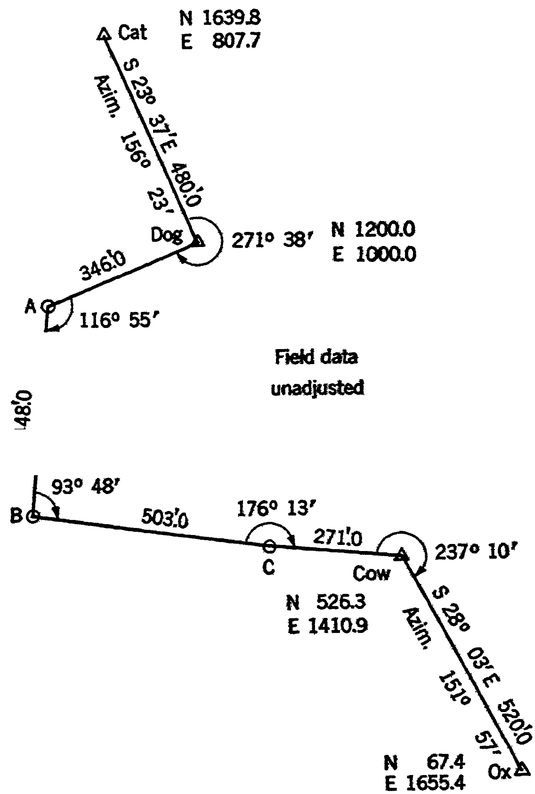


FIG. 7 —Example of a connecting traverse showing unadjusted field data.

coordinate of zero. The coordinates are computed by successive algebraic addition of the adjusted latitudes and departures. An arithmetic check is obtained when the computation is carried around to the starting point, which should have the same coordinates as before (see Fig. 6).

163. Connecting Traverse. Figure 7 illustrates a connecting traverse. It begins at the known position of triangulation station Cat and the known direction Cat-Dog. It closes on Cow and the direction Cow-Ox. The accuracy is low for illustration. The data on the figure are the field data. The positions, i.e., the coordinates, of the triangulation stations must be held fixed and the traverse adjusted to them.

1. **Compute the angular error.** Compute the directions of the fixed lines upon which the traverse begins and closes.

$$\tan \text{direction Cat-Dog} = \frac{807.7 - 1{,}000.0}{1{,}639.8 - 1{,}200.0} = -\frac{192.3}{439.8} = -0.43724$$

Cat-Dog, bearing S 23°37′ E azimuth 156°23′

$$\tan \text{direction Cow-Ox} = \frac{1{,}410.9 - 1{,}655.4}{526.3 - 67.4} = -\frac{244.5}{458.9} = -0.53280$$

Cow-Ox, bearing S 28°03′ E azimuth 151°57′

Starting with a known direction, compute the directions of the courses by applying the field angles successively. Either bearings or azimuths may be used. Azimuths should be avoided if tables of functions of angles of over 90 deg are not available. NOTE: Northwest and southeast bearings are minus angles.

By Bearings		By Azimuths
S 23 37 E	Cat-Dog	156 23
+ 271 38		+271 38
248 01		428 01
− 180 00		−180 00
S 68 01 W	Dog-*A*	248 01
+ 116 55		+116 55
184 56		364 56
− 180 00		−180 00
S 4 56 W	*A-B*	184 56
+ 93 48		+ 93 48
98 44		278 44
− 179 60		−180 00
S 81 16 E	*B-C*	98 44
+ 176 13		+176 13
94 57		274 57
− 179 60		−180 00
S 85 03 E	*C*-Cow	94 57
+ 237 10		+237 10
152 07		332 07
− 179 60		−180 00
S 27 53 E	Cow-Ox	152 07
−S 28 03 E	Cow-Ox fixed	−151 57
+ 10′	Error	+ 10′

By either method, the error, in the direction the angles were measured, i.e., clockwise, is +10 minutes or +2 minutes per angle. If it is assumed that an error of 5 minutes per angle is allowed, the angular measurement is acceptable.

2. **Adjust angles.** Give the same correction to each angle as the chance for error is the same.

$$\begin{array}{lrcl} \text{Dog} & 271°38' - 2' & = & 271°36' \\ A & 116°55' - 2' & = & 116°53' \\ B & 93°48' - 2' & = & 93°46' \\ C & 176°13' - 2' & = & 176°11' \\ \text{Cow} & 237°10' - 2' & = & 237°08' \end{array}$$

3. **Compute directions.**

By Bearings			By Azimuths
S	23 37 E	Cat-Dog	156 23
	+ 271 36		+271 36
	247 59		427 59
	− 180 00		−180 00
S	67 59 W	Dog-*A*	247 59
	+ 116 53		+116 53
	184 52		364 52
	− 180 00		−180 00
S	4 52 W	*A-B*	184 52
	+ 93 46		+ 93 46
	98 38		278 38
	− 179 60		−180 00
S	81 22 E	*B-C*	98 38
	+ 176 11		+176 11
	94 49		274 49
	− 179 60		−180 00
S	85 11 E	*C*-Cow	94 49
	+ 237 08		+237 08
	151 57		331 57
	− 179 60		−180 00
S	28 03 E	Cow-Ox	151 57
	28 03 E	Cow-Ox fixed	−151 57
	0	Check	0

4. **Compute the latitudes and departures.** The form for computation using natural functions is shown. It should be used only when computing machines are available.

FORM FOR THE COMPUTATION OF COORDINATES

Sta.	Corrected bearings / Length	cos / sin	Unadjusted Lat.	Unadjusted Dep.	Cor. Lat.	Cor. Dep.	Adjusted Lat. / Coord.	Adjusted Dep. / Coord.
Dog	S 67°59′ W	0.37488					1,200.0	1,000.0
A	346.0	0.92707	−129.7	−320.8	+0.2	+0.5	− 129.5	− 320.3
A	S 4°52′ W	0.99639					1,070.5	679.7
B	448.0	0.08484	−446.4	− 38.0	+0.2	+0.7	− 446.2	− 37.3
B	S 81°22′ E	0.15011					624.3	642.4
C	503.0	0.98867	− 75.5	+497.3	+0.2	+0.8	− 75.3	+ 498.1
C	S 85°11′ E	0.08397					549.0	1,140.5
Cow	271	0.99647	− 22.8	+270.0	+0.1	+0.4	− 22.7	+ 270.4
Sum	1568		−674.4	+408.5		Cow	526.3	1,410.9
	Coord. diff.		−673.7	+410.9				
	Error		− 0.7	− 2.4				

5. **Compute the error.**

$$\text{Total error} = \sqrt{0.7^2 + 2.4^2} = 2.5$$

6. **Compute the measure of accuracy.**

$$\text{Accuracy} = 2.5:1,568 = 1:627$$

The survey would be rejected, but it is used for reasons explained previously.

7. **Compute the corrections to latitudes and departures.**

Cor. to Latitudes	Cor. to Departures
$\frac{0.7}{1,568} \times 346 = 0.2$	$\frac{2.4}{1,568} \times 346 = 0.5$
$\frac{0.7}{1,568} \times 448 = 0.2$	$\frac{2.4}{1,568} \times 448 = 0.7$
$\frac{0.7}{1,568} \times 503 = 0.2$	$\frac{2.4}{1,568} \times 503 = 0.8$
$\frac{0.7}{1,568} \times 271 = 0.1$	$\frac{2.4}{1,568} \times 271 = 0.4$
0.7	2.4

8. **Compute the adjusted latitudes and departures.** See form in (4) above.

9. **Compute the coordinates.** Beginning with the fixed coordinates at the beginning of the traverse compute the coordinates of each station by successive algebraic addition. An arithmetic check is obtained when the computed coordinates of Cow agree with its fixed coordinates.

164. Plotting the Traverse. Traverses may be plotted by protractor and scale. When the coordinates are available, much greater

accuracy is obtained when the stations are plotted by coordinates. When the stations are plotted, light connecting lines should be drawn to represent the traverse lines. The plotted traverse should then be checked by scaling the lengths of the courses and by measuring the traverse angles with a protractor. **The results are compared with the orginal field notes.**

The coordinates of each station should be printed near the station on the map for ease in using them.

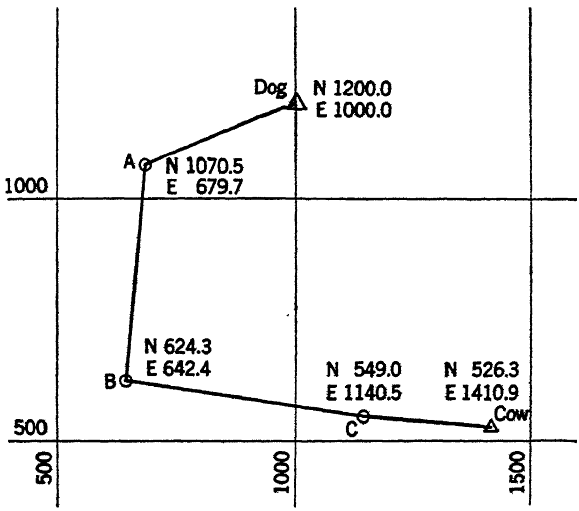


Fig. 8.—Adjusted connecting traverse plotted by coordinates.

165. Topographic Features. Objects and other topographic features that are required for the map are located by field measurements from the traverse lines. These measurements are made from traverse stations or points set at known distances along the traverse lines. They consist of the measurement of any convenient combinations of angles and distances. Any two of these measurements will locate a point. The subject is covered in Chap. XII.

PROBLEMS

In the following traverses the forward direction is indicated by the alphabetical order. All angles are measured clockwise from the back course to the forward course. For each traverse, (1) draw a sketch, approximately to scale if possible; (2) adjust the angles; and (3) compute the directions. When the lengths of the courses are given also, (4) compute the latitudes and departures, (5) compute the accuracy, (6) adjust the traverse, and (7) compute the coordinates.

The following sets of data are combined in various ways to make up traverses:

TRAVERSE ANGLES

	Set 1	Set 2	Set 3	Set 4
A	210°30′	213°05′	303°30′	54°08′
B	61 31	49 55	89 33	216 54
C	299 27	270 48	56 27	56 55
D	45 06	130 17	144 17	127 28
E	194 55	60 42	279 07	263 17
F	88 11	297 53	152 13	55 02
G	153 00	112 18	58 03	150 07
H	329 35	157 37	226 07	117 35
I	41 40	61 14	44 16	308 06
J	107 15	303 52	304 22	60 07
K	208 55	90 12	84 38	88 57
L	60 07	52 31	57 51	301 12

BEARINGS

	Set 1	Set 2	Set 3	Set 4
a	N 48°03′ E	N 25°57′ E	S 61°05′ W	N 57°04′ E
b	N 49 36 E	N 27 18 E	S 63 22 W	N 58 29 E
c	N 50 07 E	N 29 03 E	S 64 35 W	N 59 57 E
d	N 51 42 E	N 29 48 E	S 66 47 W	N 61 08 E
e	N 52 17 E	N 31 22 E	S 67 56 W	N 63 37 E
f	N 54 21 E	N 33 35 E	S 69 11 W	N 64 54 E
g	N 55 50 E	N 34 27 E	S 70 42 W	N 65 42 E
h	N 57 18 E	N 36 11 E	S 72 54 W	N 67 26 E
i	N 59 37 E	N 39 53 E	S 74 03 W	N 68 17 E
j	N 62 24 E	N 42 31 E	S 75 42 W	N 71 34 E
k	N 65 46 E	N 43 46 E	S 76 25 W	N 75 47 E
l	N 67 10 E	N 46 04 E	S 78 51 W	N 76 56 E

1–12. Compute bearings using the angles in Set 1 and the bearing for the course *I–J* found in Set 1, using line *a* for the first problem, line *b* for the second problem, etc.

13–24. As above, using angles in Set 2 and the bearing for the course *G–H* from Set 2.

25–36. As above, using angles in Set 3 and the bearing for the course *C–D* from Set 3.

37–48. As above, using angles in Set 4 and the bearing for the course *F–G* from Set 4.

49–96. Compute azimuths for Probs. 1 to 48. (NOTE: Subtract 48 from the number assigned to find the corresponding problem.)

97–120. Compute the final coordinates for the traverses given. Use the bearing given opposite the assigned problem number.

LOOP TRAVERSE 1

Traverse angles		Lengths, ft	
A	91°18′	*AB*	554.09
B	94 28	*BC*	425.31
C	109 52	*CD*	426.05
D	102 26	*DE*	345.28
E	142 06	*EA*	322.21

Coord. *B*, N 1,000.00, E 1,000.00.

LOOP TRAVERSE 2

Traverse angles		Lengths, ft	
A	96°05′	*AB*	560.27
B	95 20	*BC*	484.18
C	65 15	*CD*	375.42
D	216 22	*DE*	311.44
E	67 08	*EA*	449.83

Coord. *E*, N 1,000.00, E 1,000.00.

LOOP TRAVERSE 1		LOOP TRAVERSE 2	
	Bearing *BC*		Bearing *EA*
97	N 44°28′ W	**109**	N 34°42′ W
98	N 71 35 W	**110**	N 85 55 W
99	S 82 41 W	**111**	S 77 38 W
100	S 55 16 W	**112**	S 45 23 W
101	S 28 52 W	**113**	S 14 13 W
102	S 3 11 E	**114**	S 10 14 E
103	S 34 22 E	**115**	S 29 08 E
104	S 65 38 E	**116**	S 75 46 E
105	N 84 45 E	**117**	N 74 10 E
106	N 51 57 E	**118**	N 63 26 E
107	N 87 08 E	**119**	N 81 38 E
108	N 9 17 W	**120**	N 18 53 E

121–132. Compute the final coordinates for the traverses given. Use the coordinates for Ash, Oak, and Pine opposite the assigned problem number.

CONNECTING TRAVERSE 1

Sta.	Angle		Course	Lengths, ft
Fir	Ash-*A*	86°33′	Fir-*A*	347.15
A	Fir-*B*	223 55	*A*-*B*	449.82
B	*A*-Oak	114 48	*B*-Oak	144.76
Oak	*B*-Pine	141 36		

COORDINATES

(The coordinates of Fir are the same in all problems; N 1,000.00, E 1,000.00)

	Ash		Oak		Pine	
	N	E	N	E	N	E
121	1,326.16	903.59	1,030.88	1,846.53	1,363.40	1,907.16
122	1,333.33	932.39	956.98	1,846.00	1,282.95	1,935.38
123	1,337.95	961.69	883.41	1,839.03	1,200.35	1,956.48
124	1,340.00	991.29	810.73	1,825.68	1,116.23	1,970.30
125	1,339.47	1,020.96	739.49	1,806.04	1,031.22	1,976.74
126	1,336.35	1,050.47	670.23	1,780.27	945.97	1,975.74
127	1,330.67	1,079.59	603.48	1,748.56	861.13	1,967.32
128	1,322.48	1,108.11	539.75	1,711.15	777.35	1,951.54
129	1,311.83	1,135.80	479.52	1,668.33	695.27	1,928.51
130	1,298.80	1,162.46	423.25	1,620.42	615.50	1,898.42
131	1,283.51	1,187.89	371.37	1,567.79	538.66	1,861.49
132	1,266.05	1,211.88	324.28	1,510.85	465.34	1,818.00

133. Compute the final coordinates for the traverse given.

CONNECTING TRAVERSE 2

Sta.	Angle		Course	Lengths, ft
No. 3	2-*A*	265°48′15″	3-*A*	1,073.2
A	3-*B*	91 23 30	*A*-*B*	1,260.5
B	*A*-*C*	84 17 45	*B*-*C*	1,101.4
C	*B*-*D*	274 15 15	*C*-*D*	2,505.6
D	*C*-8	261 56 00	*D*-8	987.8
No. 8	*D*-9	115 29 15		

FIXED COORDINATES

Sta. No.	x, ft	y, ft
2	1,872,534.2	942,531.5
3	1,872,364.8	943,425.1
8	1,872,328.3	947,371.8
9	1,872,373.9	948,457.7

CHAPTER VIII

THE LEVEL AND BENCH-MARK LEVELING

166. Leveling. The importance of elevations cannot be overestimated. Gravity plays such an important part in every operation that it must be always considered in design. In particular, any facility for the movement of materials or personnel must be held to carefully established grades. Floors must be kept level to avoid hazards, simplify plant revision, provide safe storage, etc. Monorails and gravity pipe lines must be carefully graded. Machine and jig alignments can usually be established more quickly and cheaply by using surveying levels rather than shop levels, and in the field every structure and every road or drainage ditch requires careful leveling.

167. The accuracy requirements for leveling are usually much higher than for horizontal measurement. Fortunately, the higher accuracy is easier to obtain. The spirit level is itself a very sensitive instrument, and the fact that the line of sight is independently made horizontal at each setup prevents the accumulation of angular errors.

168. The Level Instrument. The engineer's level consists of a telescopic line of sight of relatively high magnification (about 25 diameters) and a relatively sensitive spirit level, the bubble of which moves one graduation when the instrument is tipped about 20 seconds of arc.

The spirit level is adjusted so that the line of sight is horizontal when the bubble is centered.

The telescope and level with their supports are mounted on a vertical spindle, which fits in a vertical bearing in a leveling head. The leveling head is provided with leveling screws so that the bubble may be centered (see Fig. 1).

An adjustment is provided so that the bubble centers when the vertical axis is vertical to avoid undue leveling.

169. Two types of instruments are used in this country, the **Y level** and the **dumpy level.** The Y level can be adjusted by one man. The dumpy level requires the assistance of a rodman. The telescope tube of the Y level is supported in two Y supports. It may be rotated in these supports and changed end for end. The telescope tube of the dumpy level is rigidly attached to the vertical spindle. This eliminates a considerable number of parts, makes the instrument cheaper, and prevents

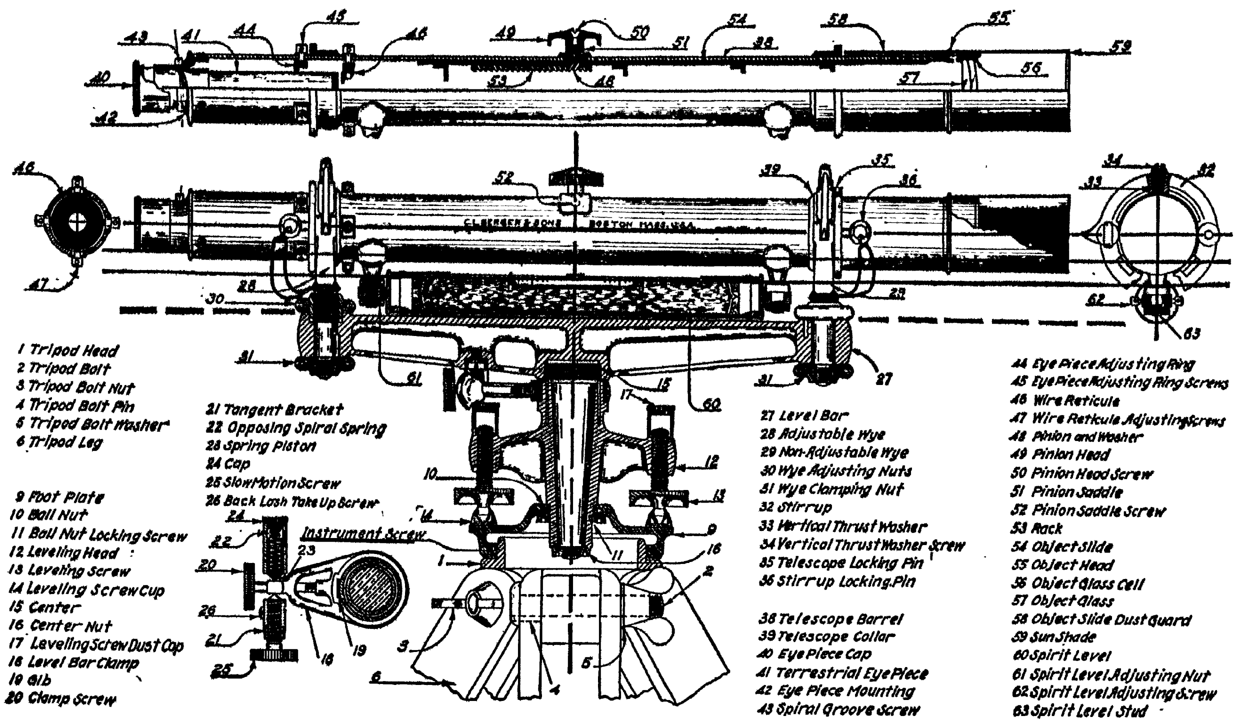


FIG. 1.—Cross section of the Berger 18-inch Y level. (*C. L. Berger & Sons, Inc.*)

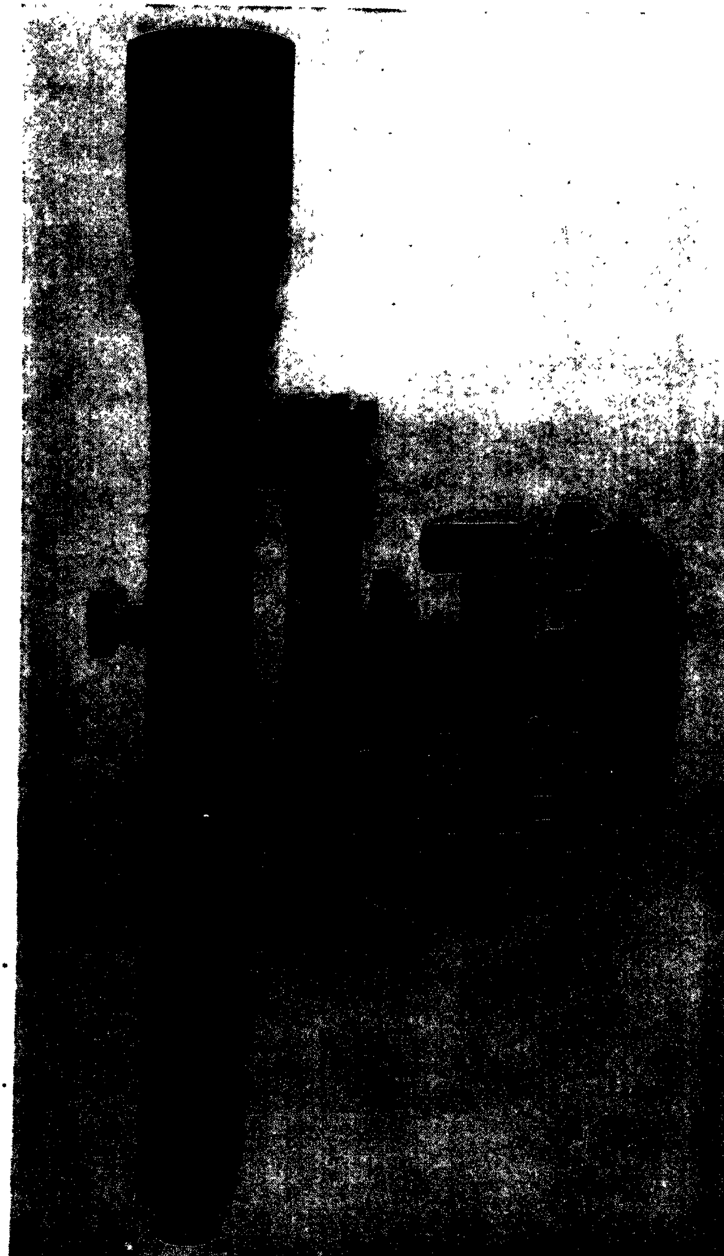


Fig. 3.—An engineer's dumpy level manufactured by W. & L. E. Gurley. (*W. & L. E. Gurley.*)

the instrument from getting out of adjustment as easily as the Y level.

170. A transit having a telescope level can be used as a level. It does not give so accurate results as a level.

171. The Rod. There are many types of level rods. The most useful for the type of work covered in this text is described here in detail. The level rod is a wooden rod graduated upward from zero at the bottom

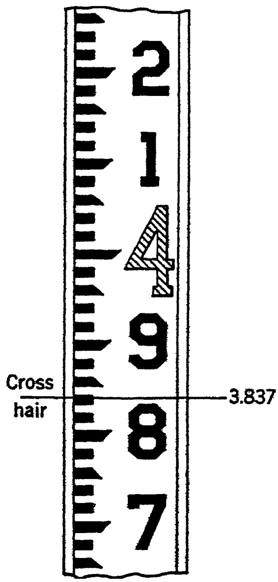


FIG. 4.—Method of reading a rod with customary graduation pattern.

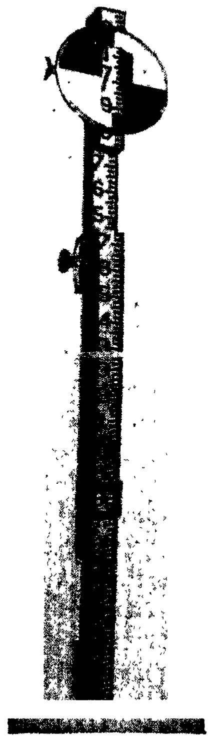


FIG. 5.—A Gurley level rod. (*W. & L. E. Gurley.*)

and provided with a movable metal target that can be clamped where desired. The rod should be graduated in hundredths of a foot. It is made in two parts. The rear section can be slid upward, and when **fully extended** the front face of the rod reads continuously from 0 to 12 or 13 feet. The graduations should be heavy and clean, so that they may be read by the instrumentman. In other words, the rod should be **self-reading.** On most self-reading rods the graduations are 0.01 foot wide and spaced 0.01 foot apart. The dividing line between the black

graduations and the white face of the rod is the exact hundredth. A standard design for these graduations is used (see Fig. 4).

172. The top of the front face of the rod (from 6.75 feet upward to about 7.20 feet) is attached to the back section. The back face of the back section of the rod is graduated downward from 7 to 12 or 13 feet. As the back section is slid upward, it runs under an index mark and vernier. The reading at the index indicates the position of a certain mark, usually the 7-foot mark on the front face. Thus, if the target is set at the proper mark and the back section of the rod is partly raised, the height of the target above the ground is indicated by the index on the rear face. A clamp is provided to hold the back section in place.

173. Bench Marks. Bench marks are marked points of known elevation above any datum. They should be objects that are easily recognized, easily found, not likely to move, marked by an identifying number, round on top, and set low with respect to the surrounding ground. The best are cross marks or bronze tablets set in old masonry with good foundations. But almost any object can serve as a bench mark. Monuments set flush with the ground, certain parts of fire hydrants, nails in trees, and even stakes are used.

174. Bench-mark Leveling. Bench-mark leveling, sometimes called **differential leveling,** is the process of determining the elevation of a series of bench marks. It is always a control survey and therefore usually performed with considerable precision.

175. Method. Set up the level near a bench mark and in the direction of progress, and read a rod held vertically on the bench mark. Add this reading to the elevation of the bench mark. The result will be the **height of instrument** or **H.I.** Choose a firm point beyond the instrument, in the direction of progress, and at nearly the same distance from the instrument as the bench mark. This is called a **turning point** or **T.P.** Read the rod held on the turning point. Subtract this reading from the height of instrument. The result gives the elevation of the turning point. This process can be continued indefinitely, running over turning points to various bench marks in succession. The work must be carried on until a bench mark of known elevation is reached. The elevation obtained must check closely with the known elevation. Often the work is merely carried back to the original bench mark as a check.

176. Systems of Bench Marks. A system of bench marks is always in demand from the moment any work is contemplated and throughout the entire life of the project. They should be established if possible before leveling is required for the original map. Thereafter they should be maintained for mapping, construction, future changes, and for maintenance. When they are available, all leveling work can

be kept on the same datum by beginning the work at the nearest bench mark. Thus elevations can be established according to the exactly same datum used in the plans. Old and new plans will agree, leveling work can be checked whenever a bench mark is passed, and the very number of them ensures the permanence of the datum they establish. At least three bench marks should always be established so that if one is disturbed the pair that check will be known to be correct.

LEVELING PROCEDURE

177. To Set Up the Level. As with the transit, spread the legs and place them so that the footplate is level. Walk around the instrument pushing each leg firmly into the ground. Loosen two adjacent screws. Turn the telescope over a pair of opposite leveling screws. Level until bubble crosses the center of the tube. Turn telescope over the other pair of leveling screws. Bring the bubble to within two divisions of the center. Repeat over the first pair. The instrument is now only approximately leveled; but as will appear later, this is sufficient for the setup.

178. When the transit is used as a level, set up and level, using the plate bubbles in the ordinary way. Then approximately center the telescope bubble, using the vertical motion.

179. To Operate the Level. As with the transit the eyepiece must be focused on the cross hairs (see Art. 112). After the instrument is set up, do not touch it or allow anything to touch it except when and where necessary for operating it. Never straddle the legs, but always stand between them; and be particularly careful not to kick or touch the tripod while walking around the instrument.

180. To Handle the Rod. Clamp the target at the 7-foot mark. **At all times** keep the rod standing on the bench mark or turning point, except when actually moving. Keep it **balanced** and with the front face turned toward the instrument. When the instrument is set up or about to be set up in a position that requires the extended rod (**high rod**), raise the rod **all the way** and clamp it in position. If it is raised part way, the graduations are not continuous and a blunder will result. Keep the eyes on the levelman **at all times**, unless performing some necessary function that interferes. Always lower the rod to carry it.

181. To Take a Rod Reading. As with the transit, it is necessary to sight over the top of the telescope to direct it toward the rod.

1. **Focus on rod** (and bring vertical cross hair near the rod).

2. **Level precisely** with the pair of opposite leveling screws that most nearly points toward the rod (or level precisely with the vertical tangent screw if the transit is used).

3. **Read the rod** (without moving the feet).
4. **Check the bubble.**
5. **Record the reading.**
6. **Give the reading to the rodman** by voice or signal, naming all the digits read. For example, in reading to thousandths of a foot, 5.1 is read, "five point one oh oh."

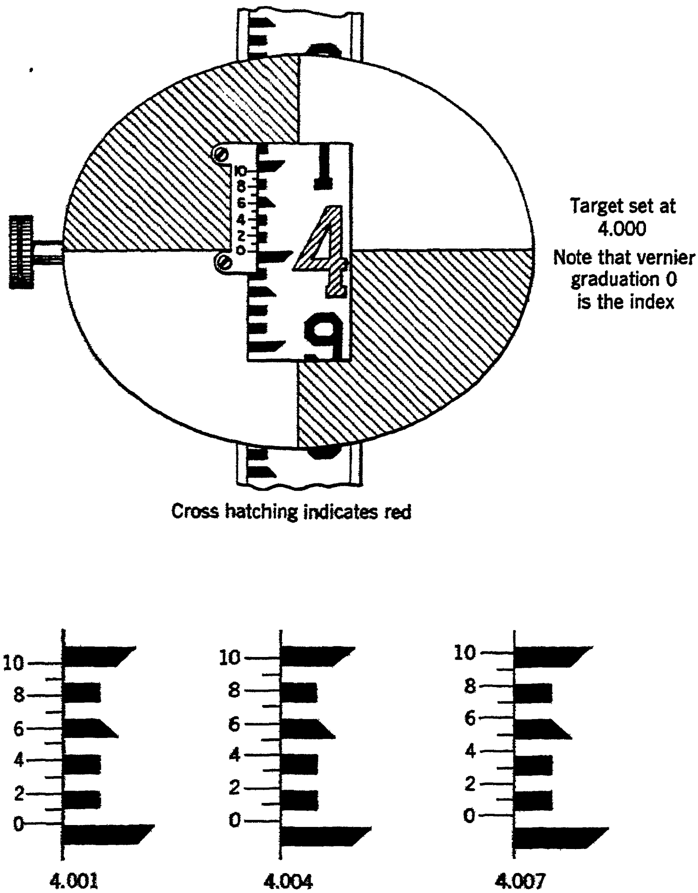


FIG. 6.—The target and the method of reading the target vernier.

7. The rodman, **while still balancing the rod,** will point to the exact reading with a pencil. If he cannot learn to do this (it is an art) or if the reading is out of reach, he will set the target at the exact reading. The target is provided with a vernier, which may be used to aid in setting the target (see Fig. 6).

8. The levelman will note whether or not the pencil or target comes on the cross hair. If he is satisfied, he calls or signals "all right" and both men record the reading.

If he is not satisfied, he reads the rod again and gives another reading or the same reading as the case may be. The rodman resets the pencil or target. If high rod was used, the levelman will call or signal "high rod" instead of the new reading and the rodman resets the rod by extending it **all the way** before the second reading is taken.

The levelman will often notice that there is a slight discrepancy between the first reading and the pencil or target position in reading to thousandths. The first reading is the correct one if the difference is 0.003 foot or less. If more, the reading is repeated, for a blunder has been made.

When there is a wind, balancing the rod does not ensure perpendicularity. The levelman will have the rodman plumb the rod according to the vertical cross hair and wave the rod backward and forward slightly. He reads the lowest point touched by the cross hair.

Communication should be by voice, if possible. Often, however, leveling is done near construction where the noise makes signals necessary.

Signals should be chosen that are easy to see and to remember. Often the best signal is an imitation in pantomime of the action desired. The signals given below are suggested.

SIGNALS

1. **All right.** Hands outstretched sideways, palms forward and moved up and down together.

2. **Plumb the rod.** Hand over head, elbow straight, palm forward and inclined in the proper direction.

3. **Wave the rod.** Both hands over head, palms forward, swung back and forth together.

4. **High rod.** Both hands extended outward to the sides, palms up, and the arms moved up to vertical together.

5. **Raise for red.** When the foot mark is invisible, the levelman reads and memorizes the tenths, hundredths, and thousandths and then calls "raise for red" or extends one hand forward, palm up, and raises it a little. The rodman lifts the rod slowly and exactly vertically. The foot mark is read when it appears.

6. **Take, or this is, a turning point.** One hand moved in a horizontal circle over the head.

7. **Kill the target.** Hand in front of the body, palm down, and moved up and down quickly. Sometimes the target covers the part of the rod that must be read. This signal is then given.

8. Kill the brass. Same signal as "high rod." Sometimes brass strip that is attached to the rear half of the rod at the bottom and fits around the front of the rod conceals the reading. By partly extending the rod the brass is moved upward out of the way. The rodman can always judge by the relative positions of the instrument and the rod whether "high rod" or "kill the brass" is meant.

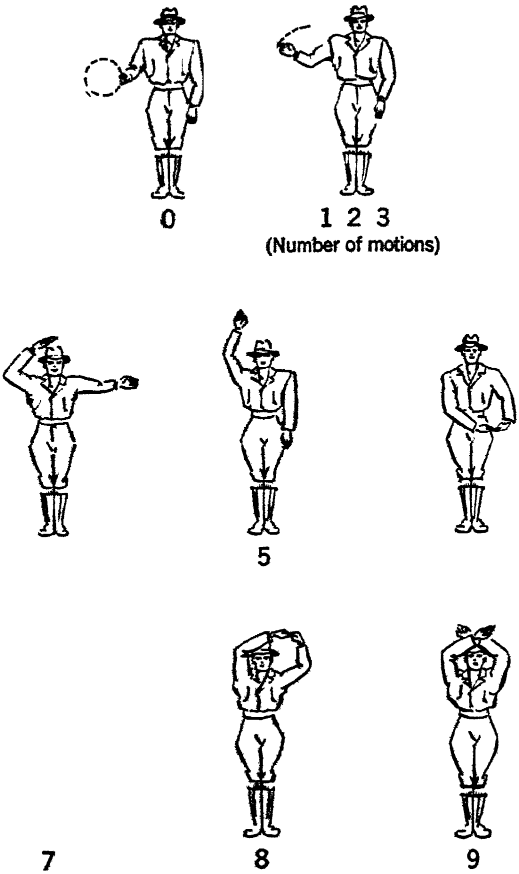


FIG. 7.—Signals for numbers. Either side of the body can be used for any number.

9. Turn the rod around. A small horizontal circle made with the forefinger. It is given when the back or side of the rod is turned toward the instrument.

10. Turn the rod right end up. An imitation of the motion of turning the rod right end up with two hands.

See Fig. 7 for signals for rod readings.

BENCH-MARK LEVELING PROCEDURE

182. (See Figs. 8, 9, and 10.) The work begins at a bench mark of known or assumed elevation, here called B.M. 5. Both levelman and rodman record the elevation (30.476) and description of B.M. The rodman holds the rod on the B.M. The levelman sets up where he can observe the rod and not more than 150 to 200 feet away. The reading 2.178 is taken, checked, and recorded by both men. The rod-

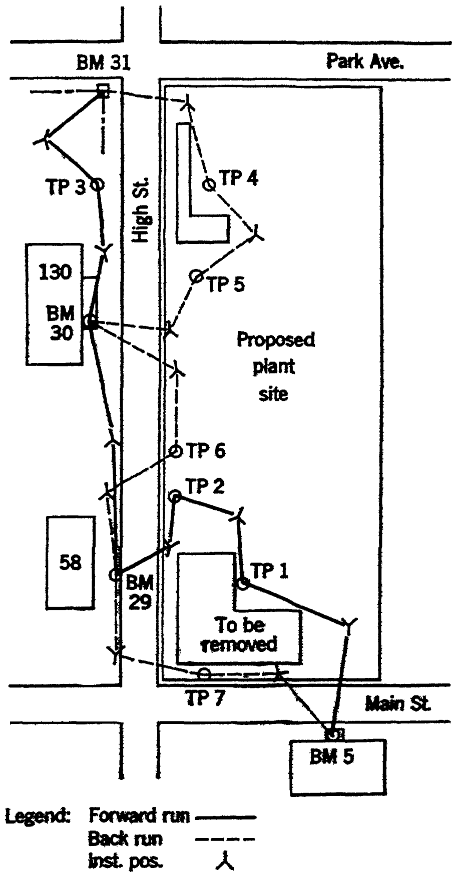


FIG. 8.—Plan of bench-mark leveling.

man paces the distance to the level. He paces out an equal distance from the level toward the desired location of a T.P. An experienced rodman can estimate the distance without pacing. He must choose a turning point having the following specifications:

1. Rod held on it must be visible from level.

2. Firm, and round on top. If no point can be found, a stake should be driven for a T.P. The point is covered with keel (lumber crayon) and numbered **before being used.**

While the rodman is so engaged, the levelman computes the H.I. (32.654).

The rodman holds the rod on T.P., and the reading 3.689 is read and checked. The levelman picks up the instrument and moves forward. The rodman computes the H.I. (32.654) and the elevation of the T.P. (28.965) in the meantime.

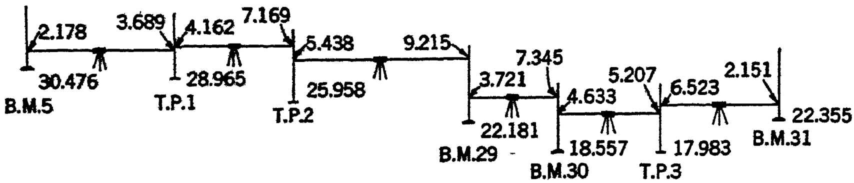


FIG. 9.—The principle of bench-mark leveling.

The levelman sets up, and the reading 4.162 is taken and checked. When the rodman comes up to the instrument after he has paced the distance, the two men check their value for the elevation of the T.P. (28.695), the levelman having computed it as the rodman comes up.

The process is continued thus. It is essential that every B.M. shall also be a T.P.

B.M. LEVELING-HIGH ST., MAIN TO PARK

Sta	+	HI	−	Rod	Elev.
BM5	2.178	32.654			30.476
TP1	4.162	33.127	3.689		28.965
TP2	5.438	31.396	7.169		25.958
BM29	3.721	25.902	9.215		22.181
BM30	4.633	23.190	7.345		18.557
TP3	6.523	24.506	5.207		17.983
BM31	4.528	26.883	2.151		22.355
TP4	5.812	26.517	6.178		20.705
TP5	6.218	29.011	3.724		22.793
BM30	7.083	25.646	10.448		18.563
TP6	5.578	27.053	4.171		21.475
BM29	9.511	31.708	4.856		22.197
TP7	8.235	33.622	6.321		25.387
BM5			3.139		30.483
	73.620		73.613		

π Smith Date
Rod Jones Fair, No Wind
76°F.
Level Berger 12978

Precise B.M Disk Set in Top Step of Entrance #125 Main St.

"R" in Corey F.H. Opp. #58 High St.

X in Stone Top Step #130 High St.

□ in Conc. Base Iron Fence S.W Cor. High St. and Park Ave.

Arith. Ck 30.476
+73.620
104.096
− 73.613
30.483

Error +.007

FIG. 10.—Form of field notes used with bench-mark leveling.

The rod column is not used in bench-mark leveling. It can be omitted.

The arithmetic can be checked by adding the plus and minus columns separately and applying the sums algebraically to the original bench mark. The elevation of the final bench mark should be obtained by this procedure.

183. Down- and Uphill. The most difficult operation for the inexperienced levelman is to choose the proper location for the instrument when working downhill and uphill. In working downhill, there is a tendency to set up the level too far downhill so that it is below the foot of the rod. In working uphill, the level is often set up too far uphill where, while the plus sight may be observed, the length of the sight is so great that the following minus sight cannot be made equal to it (see Fig. 11).

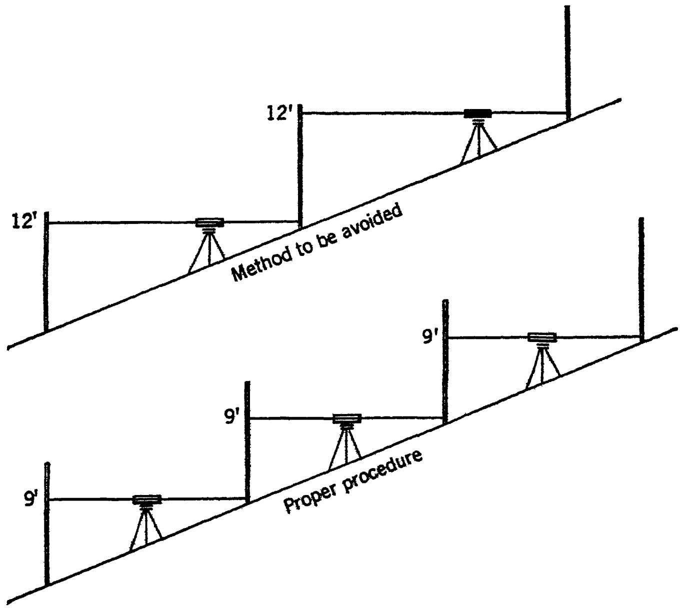


Fig. 11.—Leveling on a uniform slope.

IMPORTANT RULES

184. The following rules should be kept continually in mind during leveling.

1. Balance the horizontal length of the plus and minus sights from a single setup.
2. Have the bubble centered when the reading is taken.
3. Turn on all B.M.'s, i.e., use them as T.P.'s.
4. Keep the rod balanced on the point, facing the instrument, and watch the levelman **at all times.**
5. Mark all T.P.'s before they are used.

PROBLEMS

1–6. Figure 12 shows plans of bench-mark leveling runs. Along each line representing a sight is given the rod reading that resulted from that sight. The numbering of the T.P.'s shows the direction of progress. Place the data in the form of field notes, and compute the elevations. Show the arithmetic check. Record the error.

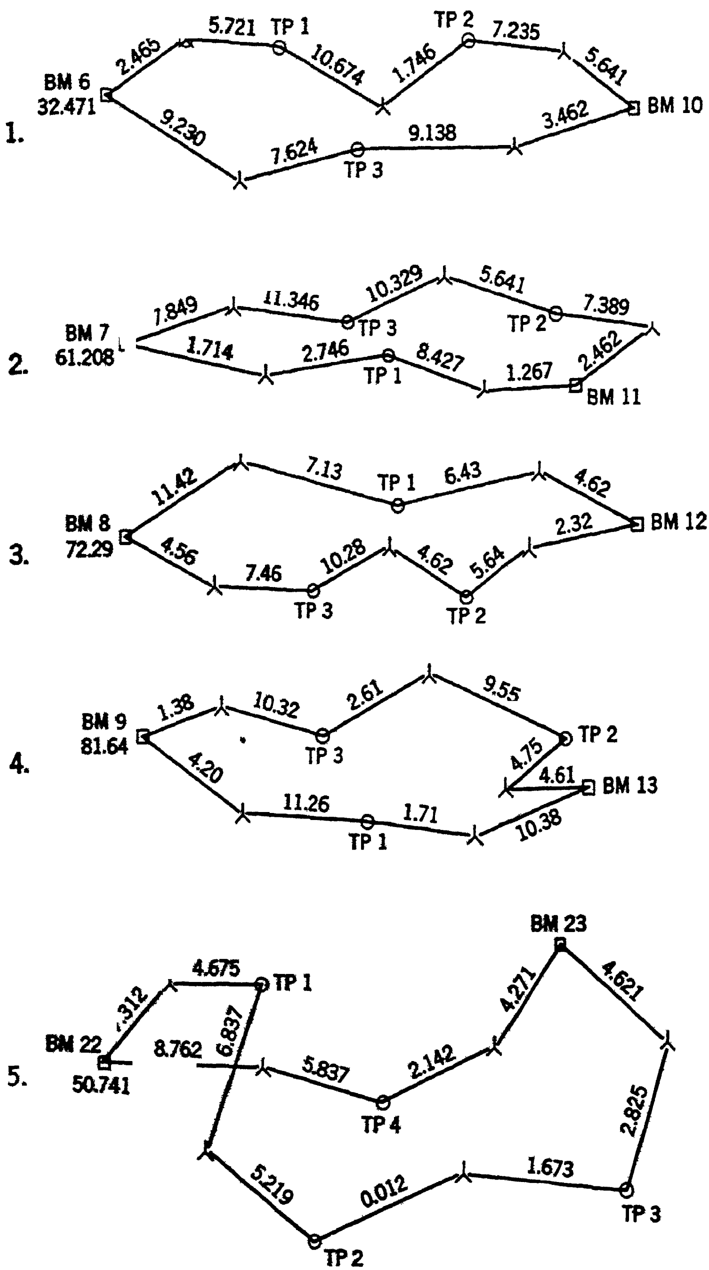


FIG. 12.—Illustrations for Probs. 1–6.

6.

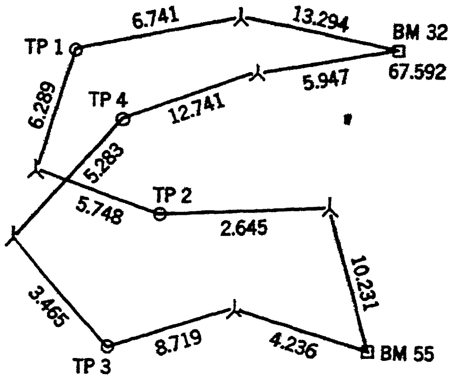


FIG. 12.—(*Continued.*)

7–10. Below are listed rod readings in the order in which they were taken in bench-mark leveling. The elevation of the starting bench mark is given first in each case. The last rod reading was taken on the starting bench mark as a check. Give the complete form of notes. Show arithmetic check and the error.

7 B.M. 65.78	8 B.M. 81.37	9 B.M. 35.23	10 B.M. 75.20
4.37	12.42	10.46	1.36
9.53	3.83	3.71	9.85
1.07	8.97	9.29	4.02
12.46	12.68	4.36	8.70
5.74	6.39	2.28	2.74
6.42	11.43	12.18	10.79
9.36	5.67	5.64	9.43
2.48	10.42	9.37	3.75
12.62	5.82	4.62	9.62
6.88	3.81	0.32	2.64
10.72	10.42	7.26	11.27
6.09	7.55	9.62	2.72

CHAPTER IX

ADJUSTMENT OF LEVEL

185. Instrument Adjustments. The reader is referred to the opening paragraphs of Chap. VI, Adjustment of Transit, which explain the importance of instrument adjustment and describe the method of presentation.

ADJUSTMENT A

186. Object. To make the horizontal cross hair lie in a plane perpendicular to the vertical axis (Y or dumpy).

Test. Point on some well-defined point, using the leveling screws. Turn the instrument left and right, using the tangent screw. The point should follow the cross hair.

Adjustment. Loosen two adjacent cross-hair adjusting screws, and rotate the cross-hair ring in the direction desired by moving the screws in their slots. Tighten the screws as much as they were loosened (Figs. 1, 2).

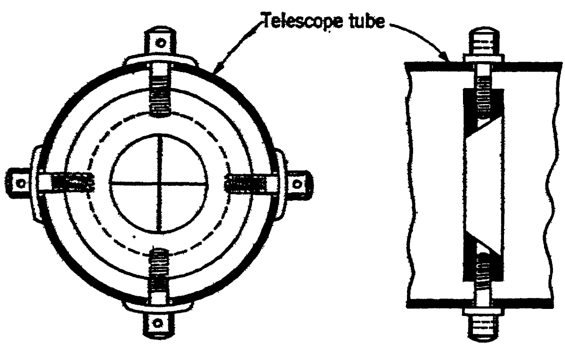
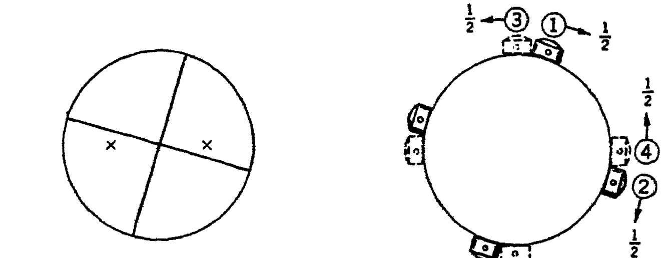


FIG. 1.—Cross hairs and reticle. The four adjusting screws are in tension.

Repeat test.

Neutralization. Use only that part of the horizontal cross hair which is near the vertical cross hair.

Geometry. A lens forms an image that is rotated 180 deg around the lens axis with respect to the object. The direction of rotation therefore is not changed by a lens as it is by a mirror.



Appearance of field in both erecting and inverting instruments

As the telescope is rotated about the vertical axis the point x moves along the line of the two positions shown

Rotate the cross-hairs counterclockwise until the point x follows the horizontal cross-hair

FIG. 2.—Level Adjustment A.

Y-LEVEL ADJUSTMENT 1

187. Object. To make the line of sight coincide with the axis of the collars.

Test. Remove the pins, throw back the clips, and sight on some well-defined point, using the tangent motion and the leveling screws. Rotate

FIG. 3.—Y-level bar with clips open. (*C. L. Berger & Sons, Inc.*)

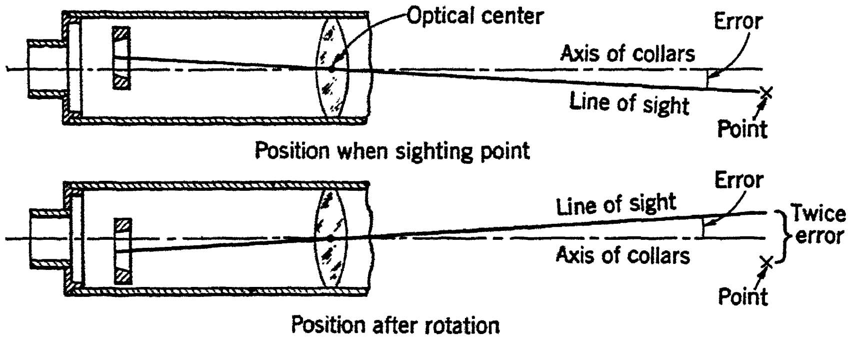


FIG. 4.—Adjustment of line of sight. The cross hairs must be raised until the line of sight moves halfway down toward point.

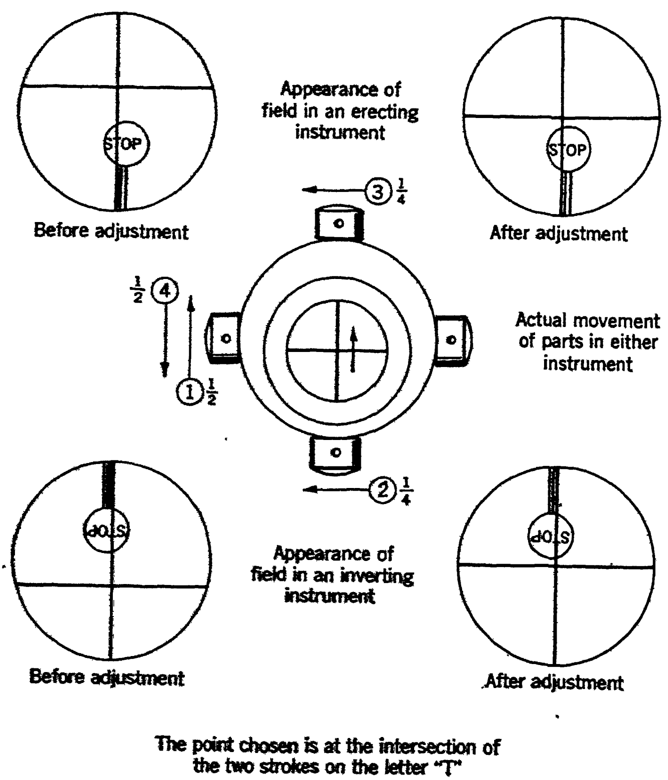


FIG. 5.—Y-level Adjustment 1. The appearance of the field of view after the test.

telescope 180 deg in the Y's around its axis. The intersection of the cross hairs should remain on the point (Fig. 4).

Adjustment. Assume that the cross hairs fall above the point. Adjust as shown in sketch (Fig. 5) until the cross hairs move halfway back. NOTE: The cross hairs are mounted as in the transit. If the vertical cross hair moves far off the point, it should also be brought halfway back by use of the horizontal adjusting screws.

Neutralization. Balance the lengths of the plus and minus sights.

Geometry. The geometry is illustrated in Fig. 4. It is explained in connection with Transit Adjustment 2 (Art. 146).

ADJUSTMENT 2

188. Object. To make the plane of the bubble tube contain or be parallel to the axis of the collars.

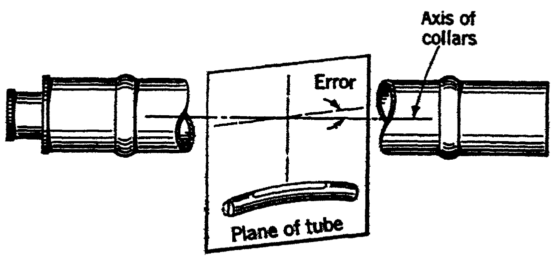


FIG. 6.—Error existing when plane of bubble tube is not parallel to axis of collars in a Y level.

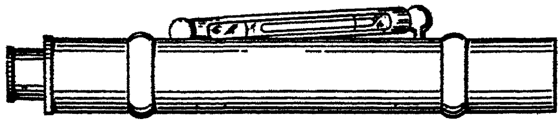
Test. Clamp the tangent motion with the telescope in line with a pair of opposite leveling screws. Center the bubble. Rotate the telescope 15 deg in Y's. The bubble should remain centered.

Adjustment. Assume the bubble moves toward the adjustment end. Adjust as shown in Fig. 7 until the bubble moves all the way back.

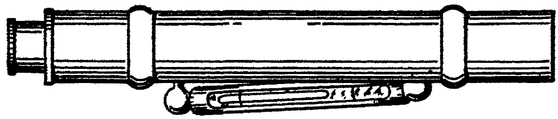
Repeat test.

Neutralization. Be sure that the level tube cannot rotate when the clips are closed. A pin on one of them should engage with a notch on the side of one of the collars to prevent rotation.

Geometry. The bubble travels in an arc that defines the plane of the bubble tube. If this plane does not contain the axis of the collars, the bubble will run toward one end of the tube or the other as the telescope is rotated in the Y's. In Level Adjustment 3 the telescope is removed from and replaced in the Y's a number of times. Unless Adjustment 2 is completed, Adjustment 3 cannot be performed, for the telescope is



Tube moved to left, bubble runs forward



Tube moved to right, bubble runs backward

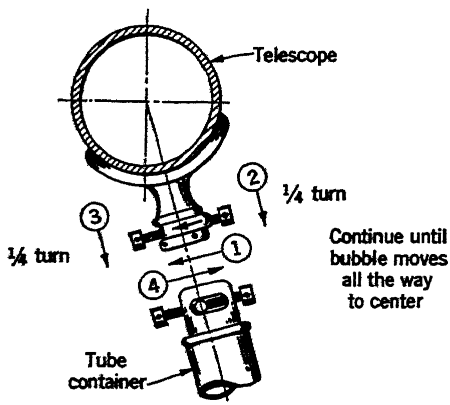


FIG. 7.—To lower adjustment end. Y-level Adjustment 2.

bound to be rotated to a slightly different position each time it is returned to the Y's.

ADJUSTMENT 3

189. Object. To make the bubble center when the axis of the collars is horizontal.

Test. Level carefully, clamped as before. Change the telescope end for end in the Y's. The bubble should remain centered.

Adjustment. Assume the bubble moves toward the adjustment end. Adjust as shown in the sketch (Fig. 8) until the bubble moves halfway back.

Repeat test.

Neutralization. Balance the horizontal lengths of plus and minus sights.

Geometry. If an error in adjustment exists, when the bubble is centered, the axis of the collars will slope by the amount of the error. When the telescope is changed end for end, the slope combines with the

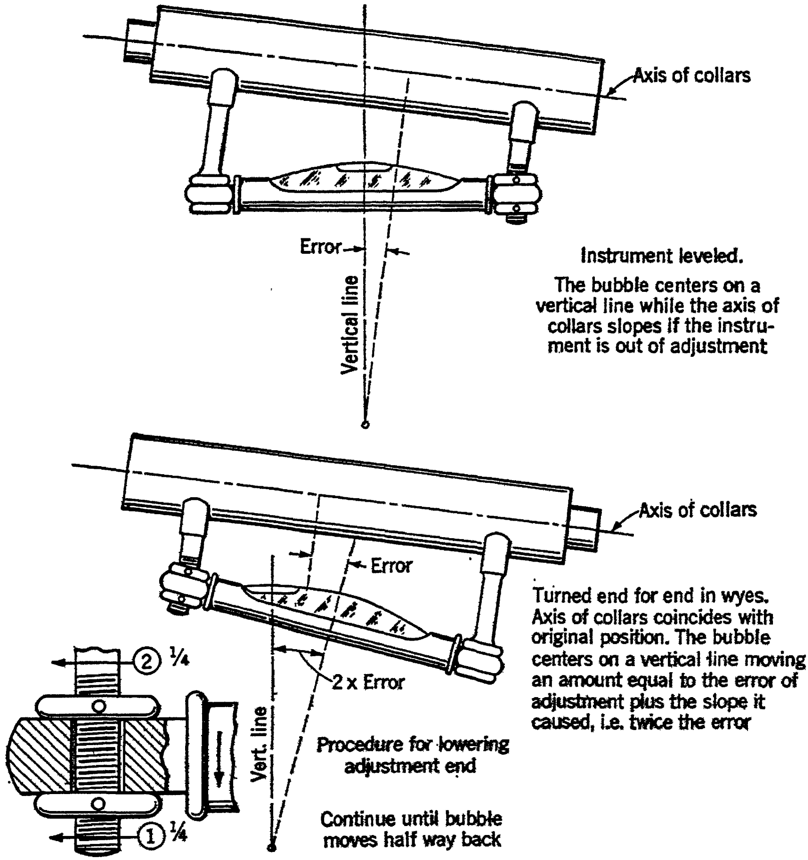


FIG. 8.—Y-level Adjustment 3.

error of adjustment to move the bubble twice the amount caused by the error of adjustment alone.

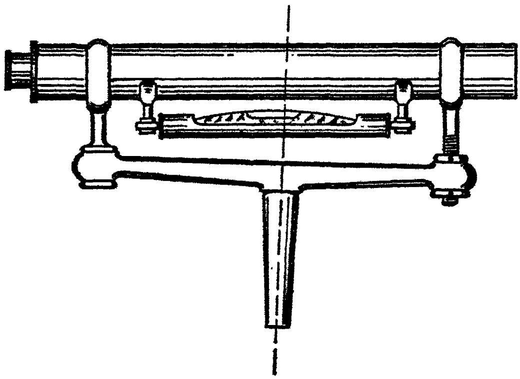
ADJUSTMENT 4

190. Object. To make the bubble center when the vertical axis is vertical.

Test. Close the clips, replace the pins, and loosen the azimuth clamp. Level approximately over both pairs of opposite leveling screws. Level carefully over one pair. Turn the instrument 180 deg around the vertical axis. The bubble should remain centered.

Adjustment. Assume bubble moves toward the adjustment end. Adjust as shown in the sketch (Fig. 9) until bubble moves halfway back.

Repeat test.



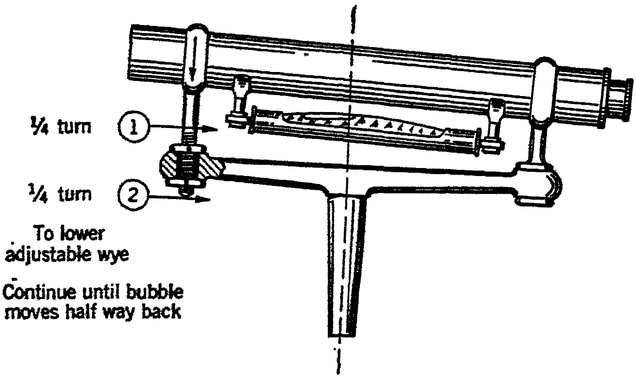


FIG. 9.—Y-level Adjustment 4. The adjustment of the Y's.

Neutralization. Relevel for any pointing of the instrument.

Geometry. The geometry is the same as for the plate bubbles of the transit.

DUMPY-LEVEL ADJUSTMENT 1

191. Object. To make the bubble center when the vertical axis is vertical.

Test. Level approximately over both pairs of opposite leveling screws. Level carefully over one pair. Turn the instrument 180 deg around the vertical axis. The bubble should remain centered.

Adjustment. Assume that bubble moves away from the adjustment end. Adjust as shown in sketch (Fig. 10) until bubble moves halfway back.

Repeat test.

Neutralization. Relevel for any pointing of the instrument.

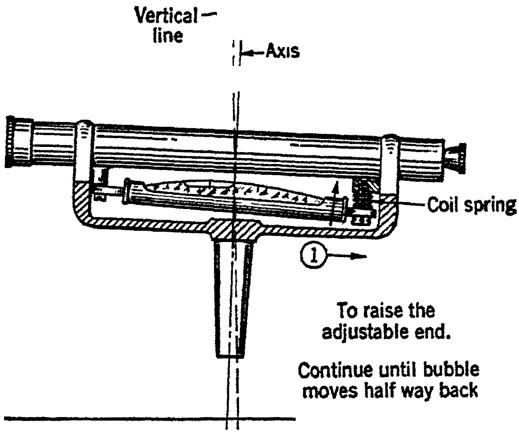


FIG. 10.—Dumpy-level Adjustment 1.

ADJUSTMENT 2

192. Object. To make the line of sight horizontal when the bubble is centered.

Test. The same test is used as for the level attached to the transit telescope. When the target has been properly set, the test is complete (see Art. 148).

Adjustment. Assume that the line of sight is too high on the rod. Level carefully and adjust the screws, holding the cross-hair ring as shown on sketch (Fig. 5) for the Y-level cross-hair adjustment, until the line of sight is brought on the target. It is brought all the way to the target, not halfway.

Repeat test.

Neutralization. Balance the horizontal lengths of the plus and minus sights.

PROBLEMS

1. Using sketches, demonstrate why, in Adjustment A, the cross-hair ring is rotated in the direction apparently required for correction in both erecting and inverting instruments.

2. Write out Y Adjustment 1 complete, assuming that after the test the cross hairs fell below the point.

3. Using a sketch of the adjustable parts and of the appearance of the field of view, show how the vertical cross hair would be centered if at the end of the test in Y Adjustment 1 it fell to the left of the point.

4. Name the various geometric conditions of the Y level itself that must be correct if the instrument is to be successfully adjusted by the usual procedures. How can it be adjusted if these conditions are not correct?

5. Illustrate by a sketch the principles of the method of neutralization of Y Adjustments 1 and 3.

6. Define the **plane of the bubble tube.**

7. Write out Y Adjustment 2 complete, assuming that the bubble moves away from the adjustment end.

8. Same as Prob. 7 but for Y Adjustment 3.

9. Describe how the field work is affected by lack of Y Adjustment 4.

10. Same as Prob. 7 but for Y Adjustment 4.

11. How does the peg adjustment of the level differ from the peg adjustment of the transit?

12. Why is the order of the peg adjustments apparently reversed from the order of the Y adjustments?

CHAPTER X

LEVELING PROCEDURES

193. The Uses and Method of Leveling. The determination of elevations with a surveying instrument, better known as **running levels** or simply **leveling,** is so simple, quick, and accurate and the importance of such determinations is so great that leveling has innumerable applications in the shop and is usually the most important operation in the field. The procedure for running levels is always the same. It consists of bench-mark leveling with one step added. At each height of instrument established by bench-mark leveling, rod readings (rod shots) may be taken on as many points as desired. The elevation of each of these points is computed by subtracting the rod reading from the proper height of instrument. Running levels, therefore, usually consists of carrying a line of bench-mark levels from a bench mark to the vicinity of the work, taking several rod shots from each height of instrument there, and, finally, carrying the line to another bench mark, or back to the original bench mark, for a check. The plus and minus sights by which the desired heights of instrument are determined constitute a control survey and for this reason must be read more precisely and usually to more decimals than the rod shots. The rod shots are taken only to the decimals of a foot necessary to the work in hand.

194. Leveling Procedure. Leveling procedure will be demonstrated by two important applications of leveling, profile leveling and leveling for a plot plan. Leveling procedures for other purposes can be devised from these examples.

195. Profile Leveling. Profile leveling is the process of obtaining the elevations of a series of points along a continuous line. The line may be straight or curved or may turn at sharp angle points. The results are plotted in the form of a continuous vertical cross section called a **profile.** The vertical scale is almost always made greater than the horizontal scale, usually in the ratio of 10:1.

196. Profiles are required for the construction of roads, drives, sidewalks, curbs, gutters, fences, highways, tunnels, railroads, pipe lines, sewers, drains, ditches, gas and water facilities, and the like.

197. Field Procedure for Profile Leveling. Figure 3 illustrates the plan and profile of an example of profile leveling. Figure 4 illustrates the corresponding field notes. The procedure is given below.

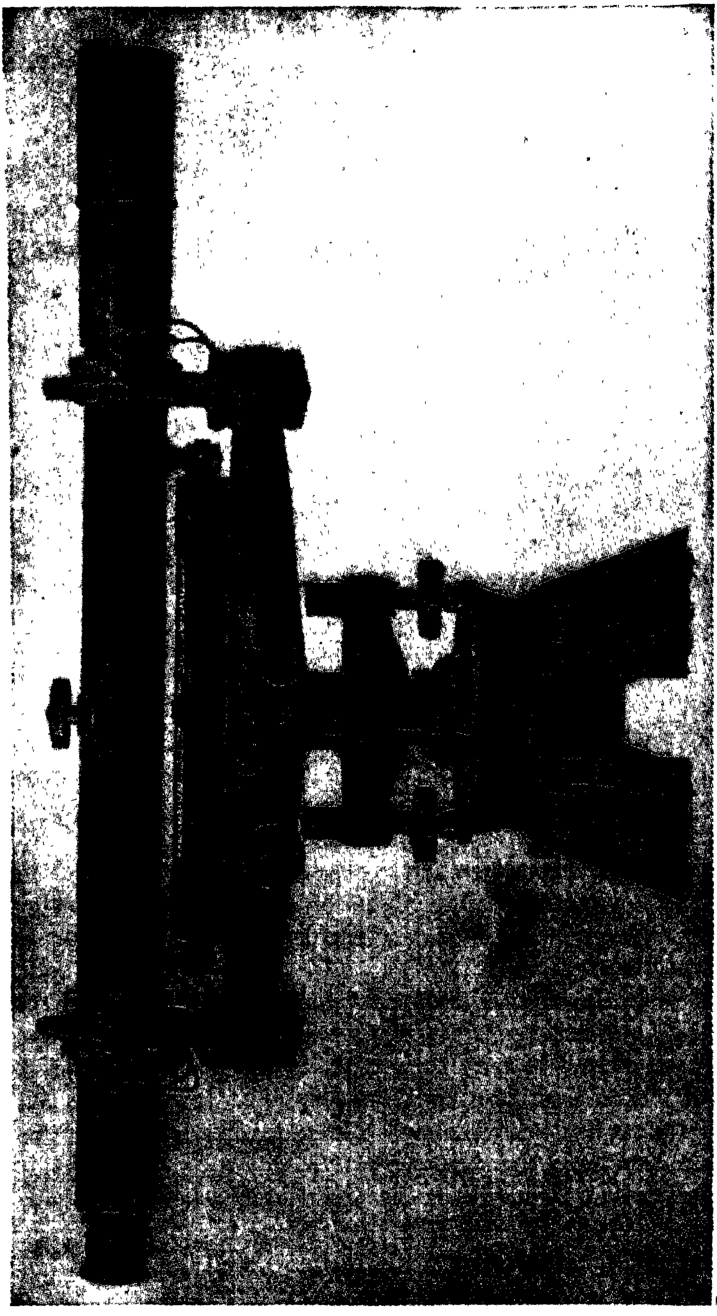


FIG. 1.—A Berger 18-inch erecting Y level. (*C. L. Berger & Sons, Inc.*)

FIG. 2.—A Berger dumpy level. (*C. L. Berger & Sons, Inc.*)

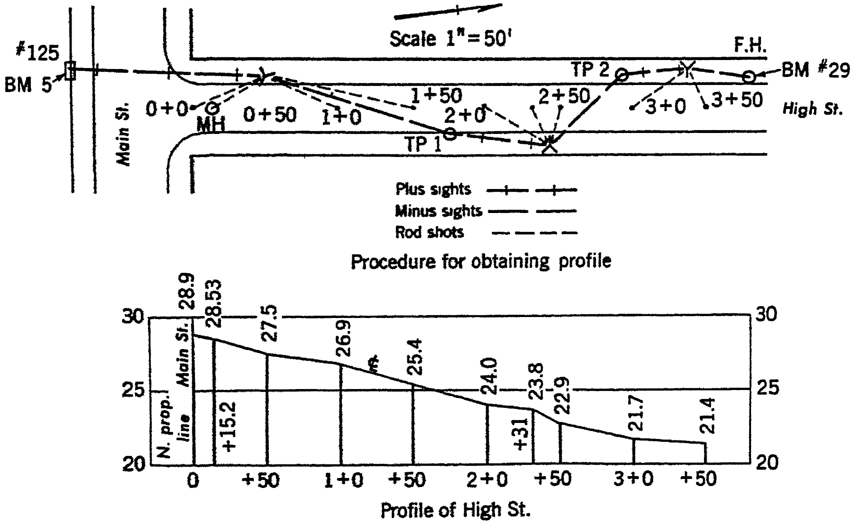


FIG. 3.—Principles of profile leveling.

PROFILE-℄ HIGH ST., MAIN TO PARK

Ch. & Recorder Roberts
π Smith
Rod Jones

Date
Clear Hot Sun
85°F.
Berger 12978

Sta.	+	HI	−	Rod	Elev.	
B.M.5	2.587	33.063			30.476	Precise B.M. Disk Set in Top Step of Entrance #125 Main St.
0+0				4.2	28.9	North Prop. Line Main St. Produced
0+15.2				4.53	28.53	Top of San. Sewer Manhole Frame
0+50				5.6	27.5	
1+0				6.2	26.9	
1+50				7.7	25.4	
T.P1	3.655	32.936	3.782		29.281	
2+0				8.9	24.0	
2+31				9.1	23.8	Break in Gd.
2+50				10.0	22.9	
T.P.2	6.006	32.581	6.361		26.575	
3+0				10.9	21.7	
3+50				11.2	21.4	
B.M.29			10.377		22.204	"R" in Corey F.H. Opp. #58 High St. Adj. Elev. = 22.185
	12.248		20.520			Error +.019

Arith. Ck.
30.476
+12.248
42.724
−20.520
22.204

FIG. 4.—Example of profile-leveling field notes.

198. Marks are placed every 50 feet along the center line desired. Each 100-foot point is called a **station** and numbered from zero. Points between stations are numbered as a **plus**, i.e., the number of feet from the last station. The enumeration is written as shown in Fig. 3.

199. The level is set up near station 0 + 0. The plus reading 2.587 is taken on B.M. 5. This is added to the elevation 30.476 to obtain the H.I., 33.063. The rod is read on Station 0 + 0, 4.2. This is called a **rod reading** or **rod shot** and is placed in the rod column. It is subtracted from the H.I. to obtain the elevation of Station 0 + 0, 28.9. Without changing the position of the instrument, all rod shots are taken until the view is obstructed or a sight of over 150 feet is required. T.P. 1 is then established. A minus shot of 3.782 is taken on T.P. 1 and subtracted from the H.I. 33.063, giving the elevation 29.281 for T.P. 1. The instrument is moved, and the process is repeated between T.P. 1 and T.P. 2, etc. The work must end on a B.M. of known elevation so that a check may be obtained.

200. The elevations of each of the stations is computed by subtracting the rod shot from the **proper** H.I. It is therefore essential that all the rod shots from one H.I. shall be recorded before the minus reading to the next T.P. Also, the minus shot to the next T.P. should be taken after all the rod shots, so that, if the field check does not indicate a blunder, this is an immediate indication that the level was not disturbed at any H.I.

201. These two considerations dictate the order of procedure, i.e., all the rod shots shall be taken at any H.I. before the minus sight to the next T.P. is taken.

202. It is evident that profile leveling is identical with bench-mark leveling except that at many H.I.'s a number of side or rod shots are taken. All the rules for B.M. leveling apply.

203. Often no B.M. exists at the end of the work. It is then necessary to carry the levels back to the original B.M. by a series of turning points in order to obtain a field check. Often it is advisable to establish several B.M.'s on the way out. This can be accomplished by merely recording the description of turning points. These are useful for giving grades for construction. On the way back they should be used as turning points so that any blunders can be isolated.

204. Under no circumstances should leveling of any type be performed without starting on, or setting, at least one bench mark. If a bench mark of known elevation is not available, one should be set and given an arbitrary elevation. The bench marks established on the original profile are later used as starting points for the leveling necessary to mark the proper elevations for construction.

205. Often the precision of profile leveling need not be so high as that of B.M. leveling. When the distance between bench marks is short and the elevations are required only to the nearest tenth of a foot, the plus

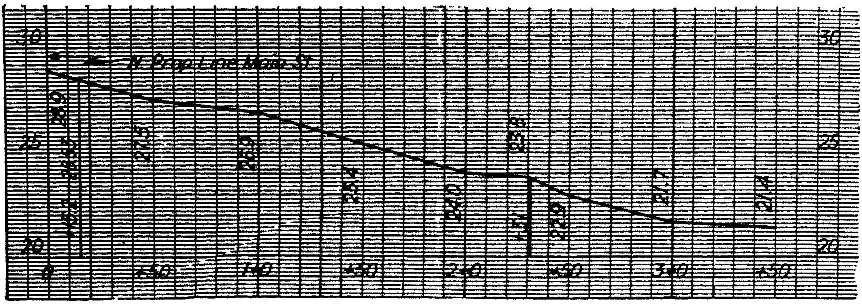


FIG. 5.—Profile paper used for plotting.

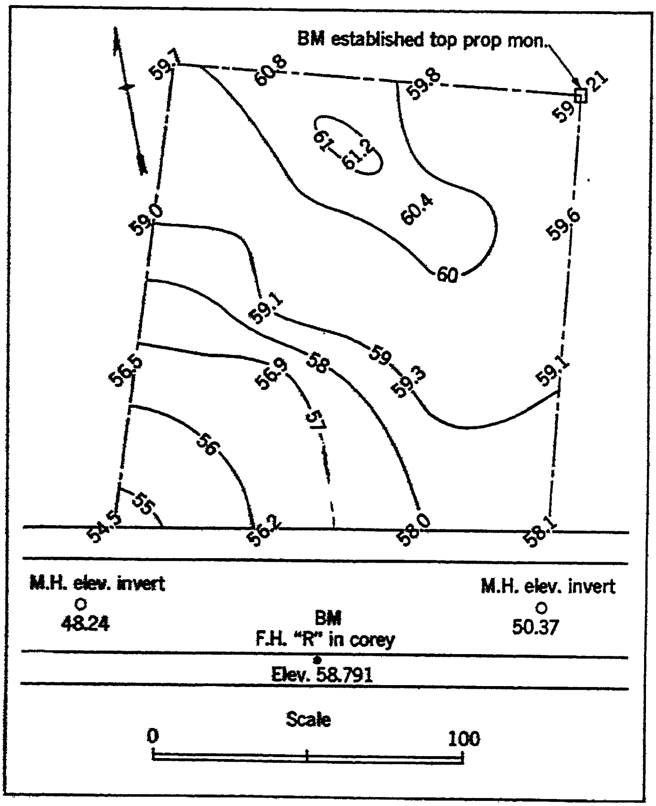


FIG. 6.—Partially completed plot plan showing interpolation of contour lines.

and minus shots should be taken to hundredths. In the illustration the plus and minus readings are taken to thousandths of a foot, as the elevation of a manhole is required to hundredths of a foot.

206. Rod shots taken on the ground, macadam roads, or surfaces that are not definite or smooth are usually taken to tenths. Sometimes they must be taken to hundredths, as on concrete roads or rail-

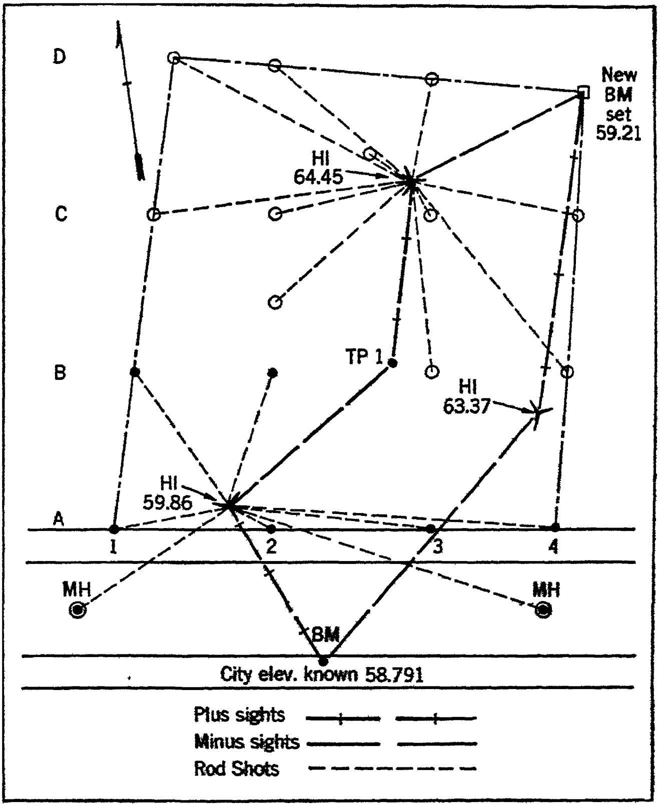


FIG. 7.—Leveling procedure for a plot plan.

road rails, etc. In that case the plus and minus shots are usually taken to thousandths.

207. The profile is plotted as shown in Figs. 3 and 5. The horizontal line at the bottom of the profile is given the highest elevation in round numbers that is still lower than the lowest point in the profile. For example, in the profile given, the bottom line could have been given the value of 10 feet or 15 feet and the profile plotted accordingly. The profile must be plotted exactly to scale, and the vertical scale should be

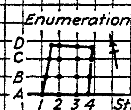
2 to 20 times (usually 10 times) as large as the horizontal scale. Frequently specially prepared **profile paper** is used for plotting.

208. A Plot Plan. When a building is planned, a considerable body of elevation data must be assembled. This includes the elevations of near-by sanitary sewers, subsurface and surface drains, water and gas mains, electric and telephone conduits, adjacent streets and rail connections, and the elevations of the entire ground surface of the property. This information placed on a plan of the property is called a **plot plan.**

PLOT PLAN PROP. A.G. SMITH

Sta	+	HI	-	Rod	Elev.
BM	1.07	59.86			58.791
MH				11.62	48.24
MH				9.49	50.37
A1				5.4	54.5
A2				3.7	56.2
A3				1.9	58.0
A4				1.8	58.1
B1				3.4	56.5
B2				5.0	56.9
TP1	6.34	64.45	1.75		58.11
B3				5.1	59.3
B4				5.3	59.1
Brk				5.3	59.1
C1				5.4	59.0
C2				4.9	59.5
C3				4.0	60.4
C4				4.8	59.6
Brk				3.2	61.2
D1				4.7	59.7
D2				3.6	60.8
D3				4.6	59.8
BM-D4	4.16	63.37	5.24		59.21
BM			4.56		58.81
	11.57		11.55		

Ch & Recorder Roberts Date
π Smith Hazy
Rod Jones 72°F.
"R" in Corey F.H. Opp Property Level
West of Prop. Invert Berger 12978
East. " " "



22' N from B2

Arith Ck.
58.79
+11.57
70.36
−11.55
58.81

20' N from C, 30' E from 2

Top Conc. Prop. Mon. N. E. Cor. Prop.
Error +.02

FIG. 8.—Form of field notes for a plot plan.

The plan must show the location of the items mentioned, the topography, and the boundaries of the property. The elevations are given by numbers lettered on the plan, and the position of the ground surface is usually shown by **contour lines,** i.e., lines connecting points of equal elevation.

209. Horizontal Measurements for a Plot Plan. When the land surveyor has marked the property lines, the engineer establishes a rectangular grid by setting stakes or plaster laths, marked for identification, at intervals of 25, 50, or 100 feet at grid intersections and at the points where the grid lines intersect the boundaries (see Fig. 6). The objects desired are located by measurements from this system.

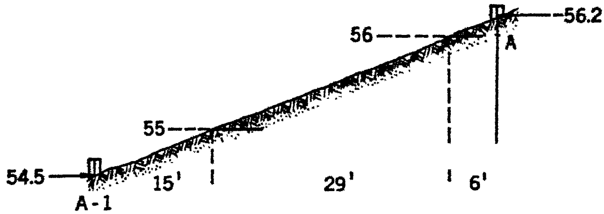


FIG. 9.—Principle of interpolating contours. Interpolation depends on the assumption that the ground slopes uniformly between two points.

210. Leveling for a Plot Plan. The leveling is carried out exactly as for profile leveling (see Fig. 7), except that usually more rod shots can be observed from one instrument position. Rod readings are taken at each stake and wherever a **break** in the slope of the ground exists between stakes. The position of these breaks is located by rectangular measurements from the stakes. Note Fig. 8. In this example two breaks are recorded. Breaks must not be omitted, for in drawing the contours it

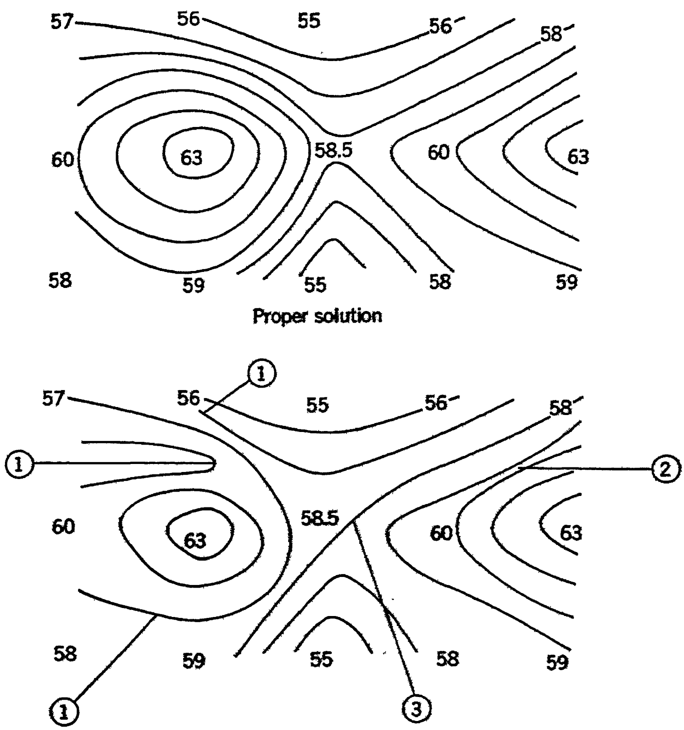


FIG. 10.—Errors in contour lines.

is assumed that the slope is uniform between points where elevations have been determined.

211. Completing the Plot Plan (see Fig. 6). A scale drawing is made, showing the points where elevations are taken and the location of all objects required. The elevation of each point is lettered near it. Frequently the dot marking the point whose elevation is given is used as

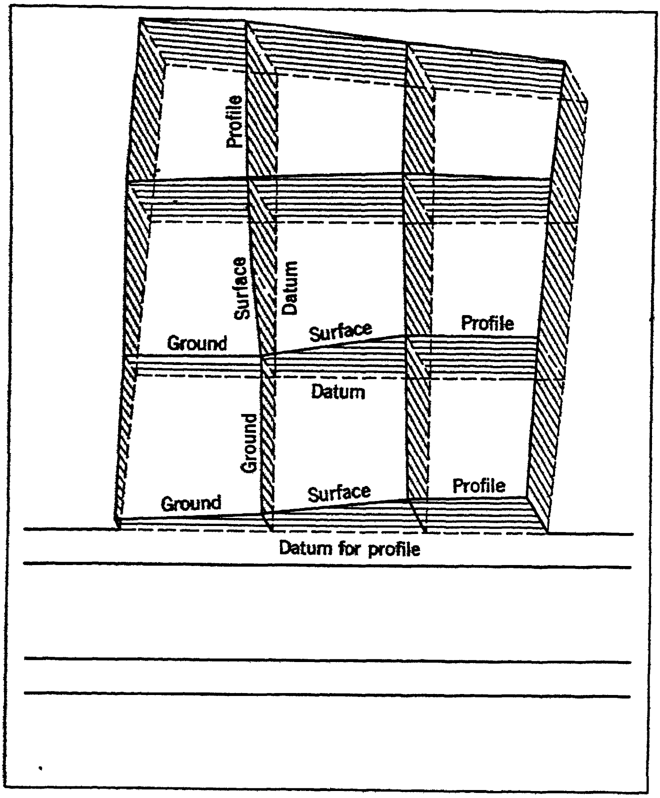


FIG. 11.—Alternate to contour lines.

the decimal point in the elevation. It is convenient to write elevations along 45-deg lines.

212. Interpolation of Contour Lines. Since, from the method of making the survey, it is known that the ground slopes uniformly between adjacent elevation points, the position of the contour lines can be interpolated between them by making the distances proportional to the differences in elevation (see Fig. 9). These interpolations can be made by eye with sufficient accuracy for most plot plans. The contour lines are

then drawn by connecting the interpolated positions by smooth curves. In drawing the contour lines the following rules should be observed (see Fig. 10):

1. Contour lines never end, meet, or cross, except in the unusual case of a vertical or overhanging cliff.

2. Unless there are data to the contrary, contour lines must be uniformly spaced.

3. Contour lines must be drawn so that the ground higher than the contour line is always on the same side of the contour line.

4. When contour lines indicate the sides of a depression in the ground with no drainage outlet, they are called **depression contours** and are marked as shown in Fig. 12, Chap. XIV.

213. Alternate to Contour Lines. The elevations of the ground surface can be shown by drawing isometric profiles (see Fig. 11).

214. Other Applications of Leveling. The procedure for determining elevations should be clear from the foregoing applications. Determining scattered elevations or any other leveling problem can be handled in a similar manner.

PROBLEMS

The following sets of field data were taken in the order given during profile leveling. Place each set in standard field-book form, and draw the profile to the following scales: horizontal 1 inch = 100 feet, vertical 1 inch = 10 feet.

	Elev.	Pt. sighted	Rod	Pt. sighted	Rod	Pt. sighted	Rod
1.	B.M. #44	B.M. #44	14.602	T.P. #1	2.218	7 + 0	5.6
	56.923	0 + 0	11.8	4 + 0	2.1	8 + 0	5.3
		1 + 0	6.7	5 + 0	8.0	9 + 0	3.4
	B.M. #45	2 + 0	3.4	T.P. #2	11.635	B.M. #45	1.843
	60.760	3 + 0	2.7	T.P. #2	4.207		
		T.P. #1	3.724	6 + 0	4.2		
2.	B.M. #20	B.M. #20	3.516	T.P. #1	4.280	7 + 0	8.3
	50.312	0 + 0	2.0	4 + 0	3.9	8 + 0	9.9
		1 + 0	7.3	5 + 0	1.4	9 + 0	9.7
	B.M. #21	2 + 0	11.1	T.P. #2	1.201	B.M. #21	9.989
	43.047	3 + 0	10.4	T.P. #2	3.016		
		T.P. #1	6.872	6 + 0	4.2		

Draw a grid 6 inches wide by 7 inches long with 1 inch intersections, and place the given elevations at the intersections in the same arrangement as printed here.

3. Draw the 5-foot contours. No depression contours are necessary.

77.0	73.0	68.0	77.0	81.0	85.0	77.0
77.0	71.0	80.0	86.0	83.0	95.0	85.0
80 0	72.0	80.0	95.0	78.0	85.0	89.0
79.0	86.0	77.0	82.0	83.0	73.0	84.0
78.0	80.0	86.0	72.0	73.0	68.0	80.0
80.0	71.0	75.0	79.0	68.0	62.0	72.0
84.0	76.0	68.0	73.0	74.0	67.0	60.0
85.0	73.0	65.0	69.0	72.0	65.0	61.0

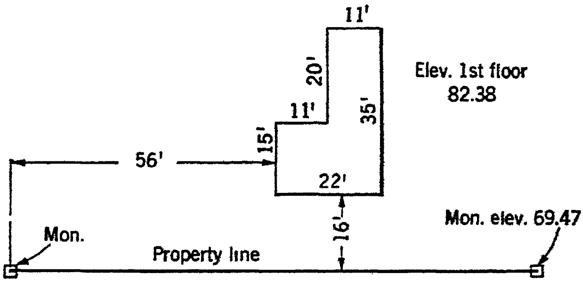
4. Draw the 1-foot contours. No depression contours are necessary.

29.3	27.6	25.6	23.0	24.0	23.1	21.8
28.5	27.3	25.9	24.0	26.0	23.9	22.0
27.5	26.8	25.8	24.0	27.2	24.6	22.9
26.4	26.0	25.3	23.0	26.0	25.0	23.8
25.5	25.1	24.7	22.5	24.9	25.3	24.9
24.3	23.9	23.0	22.0	23.5	24.7	26.3
26.0	25.8	25.3	24.0	21.3	23.8	24.3
27.4	27.4	27.0	26.1	23.5	20.6	23.0

CHAPTER XI

ESTABLISHING LINE AND GRADE FOR CONSTRUCTION

215. Location Surveys. The process of marking the position of future construction is the location survey. It is called **giving line and grade** in the field and **marking out, aligning, lining up, centering,**



Location dimensions for a house

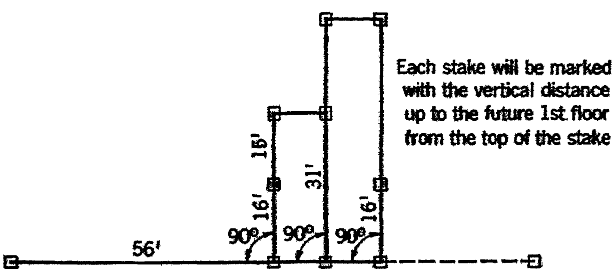


FIG. 1.—One method of staking out a house, showing stakes set and angles and distances measured.

setting gauge points, etc., in the shop. When surveying instruments are used, it consists in setting points that show the horizontal and vertical positions required by the plans.

216. Field Methods. The plans for construction always give, either by scale or by actual dimensions, the positions and elevations of the new

work relative to existing structures or to survey control marks. The dimensions of the construction shown on the plans complete the necessary data for giving line and grade.

217. For example, Fig. 1 shows the data for a house, and Fig. 2 shows the data for a curb. Indicated are the stakes and tacks that might be set in the two cases to mark position and elevation.

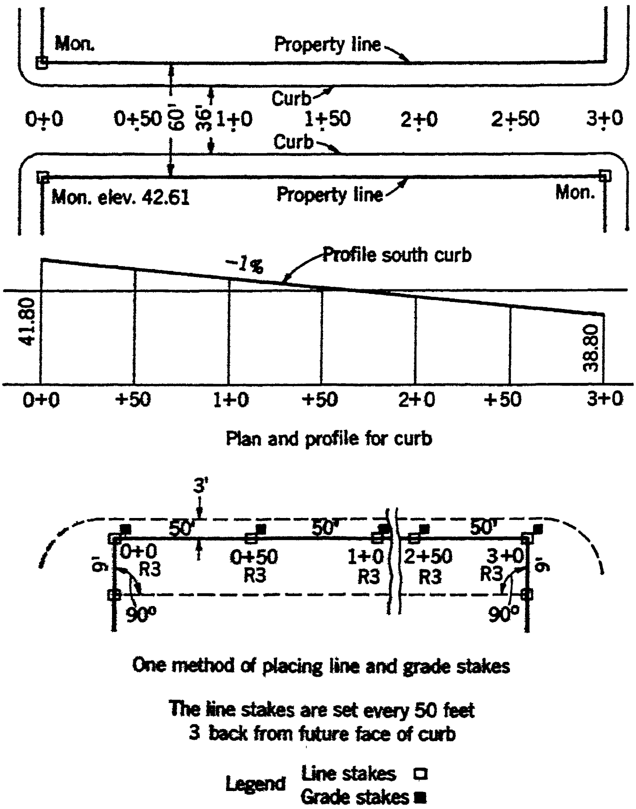


FIG. 2.—Staking out a curb.

218. The stakes are sometimes set at the corners or other points required, later to be transferred to near-by marks which will not be disturbed by the construction and from which the construction can be located by short measurements with a carpenter's rule and level (see Figs. 1, 2). Sometimes the marks are originally set clear of the work so that they will not be disturbed (see Figs. 3, 4). Sometimes the positions are marked on the work itself as construction progresses.

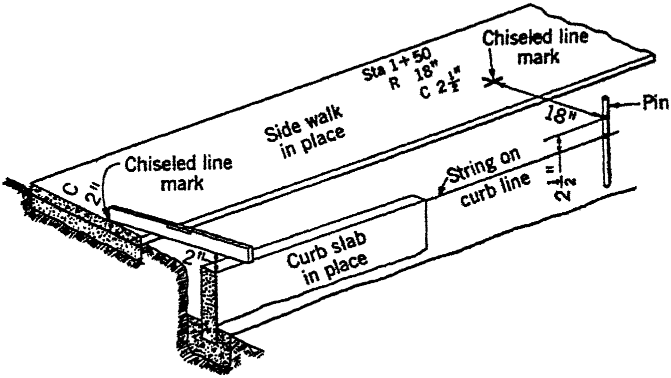


FIG. 3.—Setting pins to give line and grade for curb.

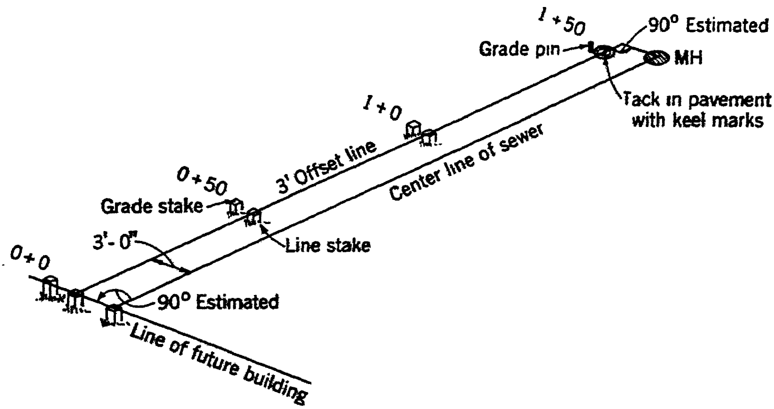


FIG. 4.—Line and grade stakes for a drainpipe.

219. When it is necessary to stake out long lines for construction, the positions are numbered as for profile leveling. Each 100 feet is called a **station**, and points between are called **pluses**. Stations and pluses are marked as shown below:

Distance from Beginning	Enumeration of Stations and Pluses
300.00	3 + 0
528.72	5 + 28.72
425.9	4 + 25.9

220. When a construction line must be marked so that it will not be disturbed, the marks are usually placed along a parallel line. Such a line is called an **offset line**. In looking along the true line from Station 0,

if the offset line is to the right, it is a right offset line. Thus a 4-foot right offset line means a line 4 feet to the right of the true line. Stakes on the offset line are marked with the station numbers of the points they are opposite and with the offset distance, thus:

$$4 + 73 \text{ R } 4$$

ESTABLISHING LINE IN THE FIELD

221. Marking Position. Without further examples, it is clear that the process of **giving line** consists in establishing predetermined angles and distances and placing a series of marks in line usually at given distances. The angles and alignment are almost invariably established with a transit, and the distances are measured with a steel tape.

222. Setting a Predetermined Angle. An angle can be established by setting up the transit at the angle point, or vertex, and proceeding as follows:

1. Set the *A* vernier at zero, using U.M.
2. Point at mark, using L.M.
3. Turn off the angle, using the U.M., setting the *A* vernier accurately at the value of the angle.
4. Set a mark on the new line.

Obviously such an angle can be set only to the nearest half minute. When greater accuracy is desired, the angle thus established must be

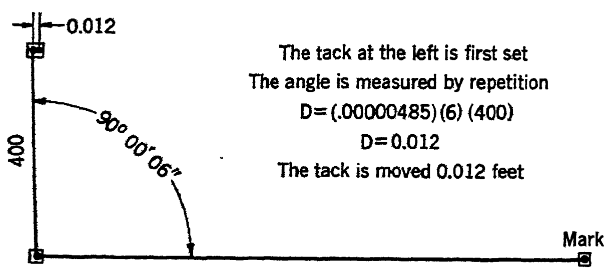


FIG. 5.—Establishing an accurate angle

measured by repetition and the tack adjusted accordingly. The distance the tack must be shifted is computed by trigonometry (see Fig. 5). The following formula is useful and accurate if the error is not more than 3 minutes of arc.

$$D = 0.00000485SR$$

where D = distance tack is shifted
S = seconds of error
R = distance from transit to stake set

It is well to check by measuring the final angle by repetition.

223. Establishing Direction. When the direction of a line is to be established either by turning an angle from a mark or by merely pointing at a mark on line, if more than one mark is available, the mark at the greatest distance from the transit should be used to establish the original direction of the line of sight. In general, the direction of a line should be established from a line longer than itself.

224. The transit can never be set up **exactly** over a point, nor can the signal be placed **exactly** over its mark. Obviously, the longer the line sighted, the less these errors will affect direction (see Fig. 6).

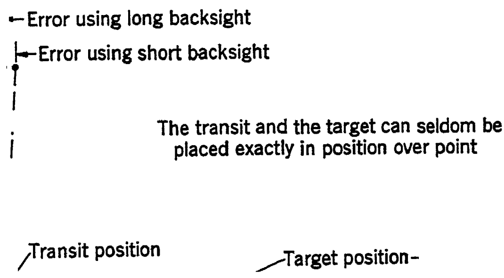


FIG. 6.—Using a long backsight reduces error.

225. Movement of the Transit. The transit is always subject to possible motion. Changes in temperature, settlement of the tripod, vibration, and readjustment of stresses in the tripod are contributing causes. Therefore, whenever a series of marks are to be set on a line, the direction of the line of sight should be frequently checked by pointing at the original mark and always checked after the last mark is set.

226. Use of Foresight. It is clear that the transit must be pointed repeatedly at certain marks. When these marks cannot be seen, much time is wasted by sending a man with a plumb bob or a range pole to them whenever a sight is necessary. This can be avoided by establishing foresights for these points by one of the following methods:

1. Instead of tacks, use finishing nails driven so that the heads will remain $\frac{1}{4}$ in. above the top of the stakes.

2. Rig a plumb bob, range pole, or other device over the mark (see Fig. 7).

3. Choose or establish a special mark anywhere on line.

227. To Establish a Foresight. After **taking line** by pointing on a plumb bob or range pole held at the mark, look for an object that happens to be anywhere on line. Letters on signboards are especially useful for this purpose. If nothing is available, choose any flat vertical surface on line. Set two pencil marks in line on this surface, one about

6 inches above the other. Using a pencil and yellow keel, construct a target that offers a precise line centered on these marks and one that is easily found and identified.

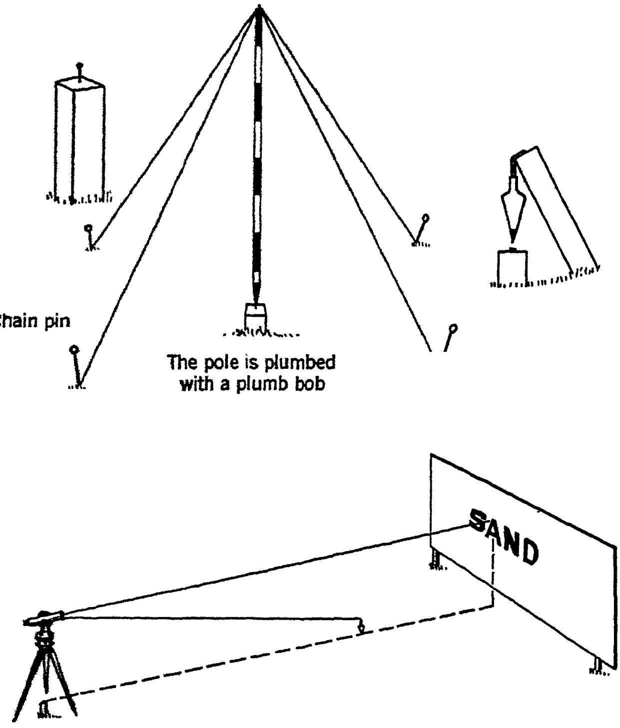


FIG. 7.—Typical foresights.

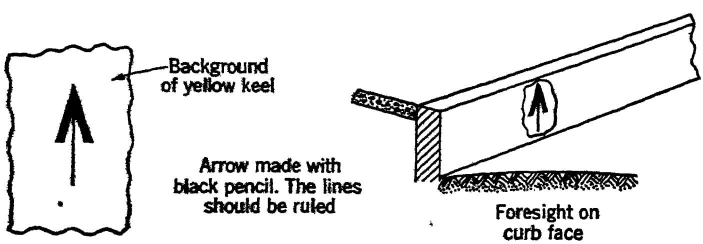


FIG. 8.—A type of foresight that is easily established.

228. Permanent Construction Lines. On large construction, important lines should be permanently marked with monuments, and permanent foresights should be built at each end.

229. Setting Marks for Line and Distance. Usually, when a series of marks are set in line, they must also be set at required distances. In most cases the marks

used must be stakes and tacks. As this process is somewhat difficult, it is described here in detail. The process of setting stakes and tacks for line only should also be clear from this description.

The transit is set up over a mark on line, pointed at another mark on line, and a foresight is established if desirable.

Usually the measurement starts at the transit. The rear tapeman holds the zero end of the tape near the transit while the head tapeman carries all his equipment forward, holding the reel so that the tape unwinds. When the proper distance is reached, the head tapeman stops and the rear tapeman places himself under the

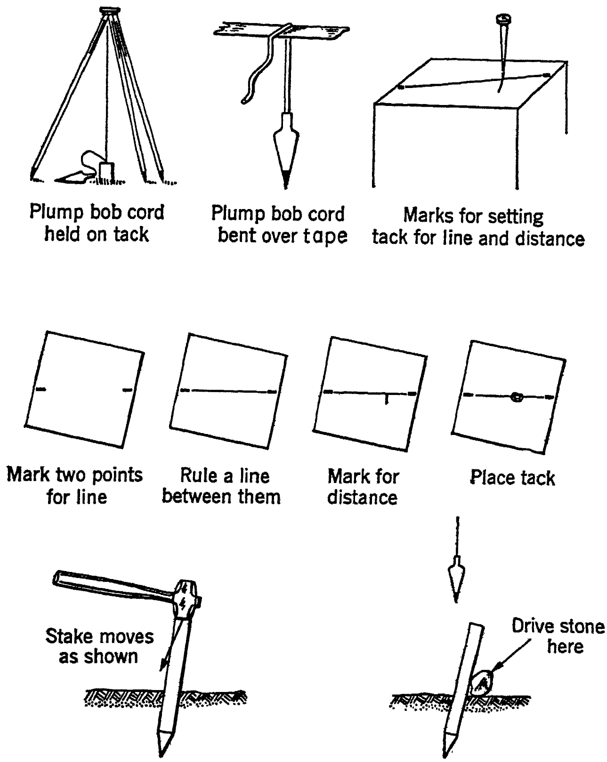


FIG. 9.—Location taping details.

transit, being careful to avoid touching the tripod legs. He holds the zero mark of the tape on the tack if conditions permit the tape to be level in this position. He can steady the tape against the stake, but he must take the full tension with his hand.

If the tape must be raised above the stake, the rear tapeman loosens the plumb-bob cord on the transit until he has about 8 inches slack. He places the bob on the ground and holds the cord taut by pressing it against the tack with one hand. With the other hand he controls the tape so that the zero mark is at the cord (see Figs. 9, 10).

The head tapeman bends his plumb-bob cord over the tape at the proper graduation, holding it in position by squeezing the cord and tape together with one hand.

With the other hand he applies the tension, holding the tape at the proper height to keep it level. When the plumb bob is steady he calls "line for stake." The transitman directs line by signal or voice, giving the compass direction and the amount of the movement, thus, "north two-tenths," "south five-hundredths," etc. When the cord is brought nearly on line, he signals or calls "good for stake."

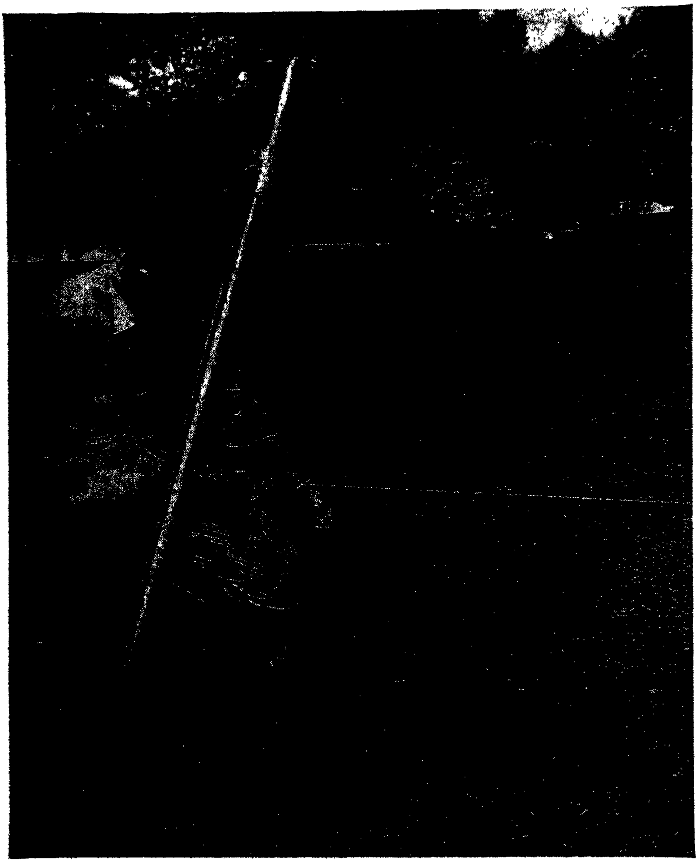


FIG. 10.—Holding bob string taut against tack.

At this call the head tapeman releases the plumb bob so that it drops vertically, marking the ground slightly with its point. The longest dimension of the top of the stake is kept in the direction of measurement, and the stake is driven at the mark to a depth of 2 or 3 inches. The position of the stake is then checked. The head tapeman calls "distance," stretches the tape, and checks the distance. He then calls "line for stake" and holds the bob for the transitman, moving it as directed. The stake is driven according to the results of this check, the transitman watching it go down as long as it is visible. He will call "keep it south" or "south one-tenth" as the need arises.

230. Driving a Stake. It takes considerable skill to drive a stake so that the top remains in position. Frequently the head tapeman makes a second check when the stake is partly driven home. The top of the stake invariably moves toward the person driving it. Slight corrections can therefore be made by driving it from the position toward which the stake should move (see Fig. 9). When greater corrections are necessary, the ground should be pounded beside the stake. Still greater corrections can be made by driving stones into the ground beside it. Tapping the side of the stake to align it merely loosens the stake and sometimes breaks it.

When the stake is driven well into the ground and found to be out of position, the only recourse is to drive another stake beside it. If it is withdrawn, it will follow the old hole when redriven.

The stake must be driven until it is firm and usually with the top not more than a few inches above the ground.

FIG. 11.—Holding plumb-bob string and tape.

231. Setting a Tack. A pencil is placed on the top of the stake, held slanting away from the transit or preferably balanced on its point. The pencil point is lined in and a pencil mark made on line.

If the transitman cannot see the pencil, he signals or calls "raise it" and a plumb bob is substituted. The head tapeman should hold the cord as close as possible to the bob without interfering with the transitman's view. The swing of the bob can be damped by tapping the point against the top of the stake.

When he is ready, the head tapeman calls "line for tack"; and when the plumb bob (or other signal) has been brought precisely in line by directions from the transitman, the latter calls "good for tack." When he is satisfied, the head tapeman drops the bob to the stake by dropping his hand about ½ inch. Then, while holding the cord and bob in this position with one hand, he reaches the bob with the other hand and marks the point by making a hole in the stake with the point of the bob. If there is any doubt in his mind of the accuracy of the mark, the head tapeman calls for a check.

Frequently two marks are made for line near the edges of the top of the stake toward and away from the instrument, and a pencil line is ruled between them.

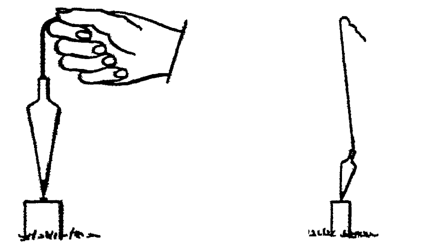


FIG. 12.—Handling plumb bob.

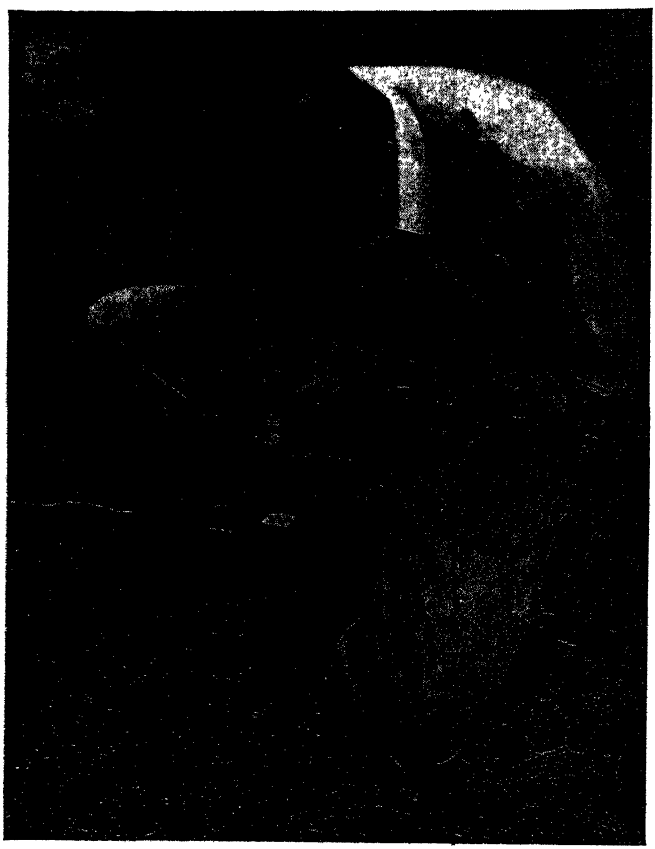


FIG. 13.—Short hold on plumb bob.

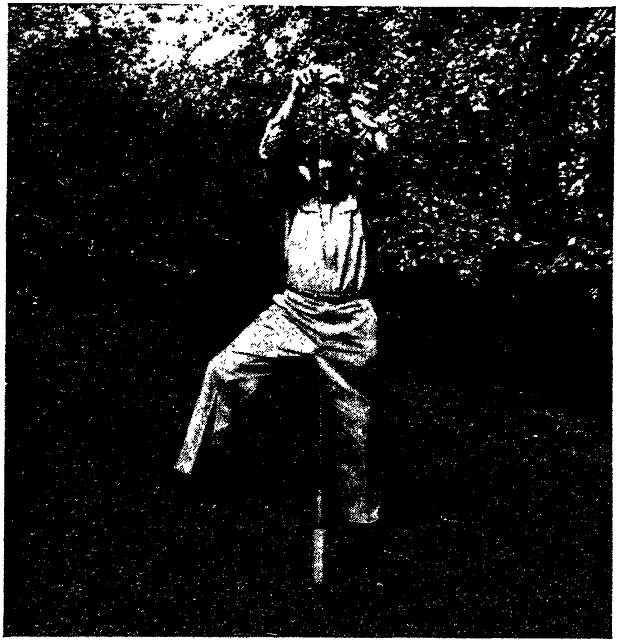


FIG. 14.—Plumbing high.

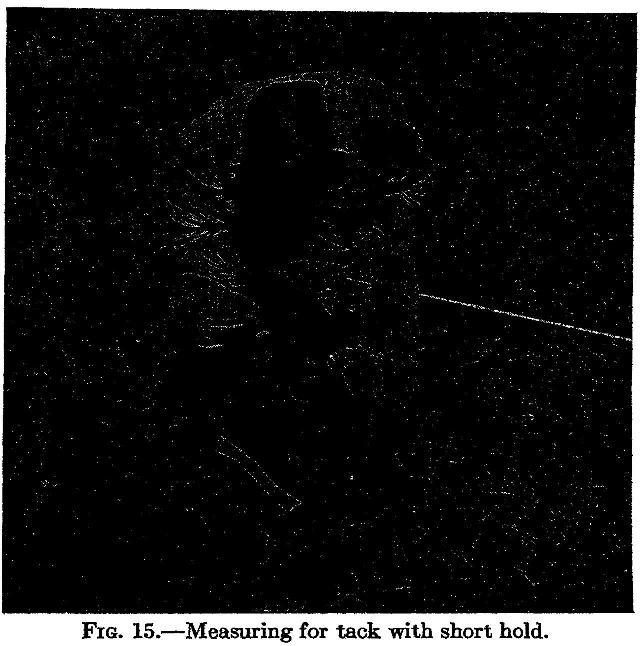


FIG. 15.—Measuring for tack with short hold.

When conditions permit, the tape is laid on the top of the stake to obtain distance. If this is impossible, a plumb bob is used. The cord is bent over the proper graduation as before, the tension applied, and the swing damped out by moving the tape up and down so that the point of the bob taps the stake. The head tapeman should keep the bob over the pencil line. The exact point is marked with the point of the bob and checked if necessary. If only one line point has been set, it is sometimes necessary to check the distance mark for line. When the tape can be laid on the

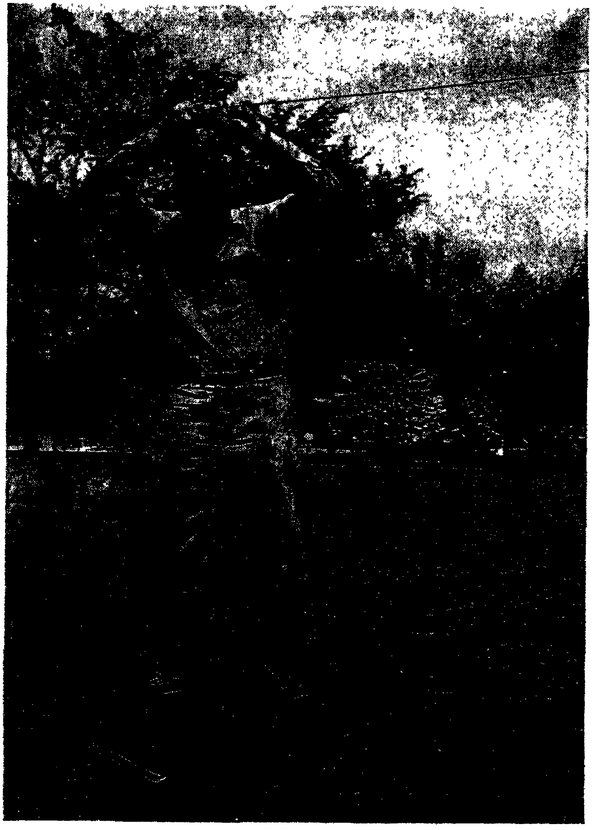


FIG. 16.—Measuring for tack with long hold.

stake, the edge of the tape can be used to transfer the line to the correct distance mark. A tack is driven at the final mark. Frequently the tack is again checked for line and distance (see Figs. 12-16).

The station number is marked on the stake with keel or on a guard stake set at a slant near it. The number of the stations should be checked by call. The head tapeman calls "station," and the rear tapeman calls the number of the station where he is standing.

The checks enumerated may seem rather excessive It is the duty of the head tapeman to decide when they are necessary. He knows by experience whether

conditions were proper for an accurate result. Too few or too many checks will often waste time. The speed and accuracy of the work are obviously entirely in the hands of the head tapeman. If the field party is shorthanded, the chief should take this position.

When the head tapeman is finished, if a full tape length has been measured, the rear tapeman drops his end of the tape and walks forward to the stake just set. In the meantime the head tapeman takes his equipment forward and drags the tape. When the zero end of the tape reaches the stake, the rear tapeman calls its station number, the head tapeman stops, and the process of setting a stake is repeated. The rear tapeman now handles the tape in the same manner as the head tapeman except that, instead of applying tension, he resists it.

232. Marks on Other Surfaces. When the marks are made on masonry, the process is simpler. Pencil lines or scratches with the plumb-bob point are used for marks. A cross is chiseled at the mark if it must be permanent. Usually the mark is circled with keel to make it easy to find.

When the stake strikes an obstruction before it is firm, the earth is cleared away and the mark is made on the obstruction.

When the surface is hard and irregular like a macadam road, a heavy nail can be driven as a mark. Often a small piece of cloth or a roofing washer is placed on the nail to make it easy to find.

233. Signals Used in Giving Line.

1. **Take line** means to point on the target designated. The rod or plumb bob is held horizontally and then placed over the point.

2. **Give line** or **line** means to give directions for bringing a target on line. To indicate this the range pole or plumb bob is merely held approximately on line.

3. **Directions for line.** The transitman gives line by motions with the hand on that side of his body which is toward the direction of motion. The palm is held toward the person receiving the signal. Slow motions indicate large distances; quick motions indicate short distances. A handkerchief is often held in the hand to increase visibility. Sometimes the distance desired is signaled in hundredths of feet, the signals shown in Fig. 7, Chap. VIII, being used.

4. **Raise it** means that the plumb-bob string or other target cannot be seen. A handkerchief is moved up and down over the transit. The tapeman should discover what is wrong and correct it. Usually the ground interferes, and more plumb-bob string should be exposed. Sometimes a better background is necessary, and the tapeman should place his trouser leg behind the string or stand behind it. Sometimes the range pole should be substituted.

5. **Good** or **all right** means that the transitman is satisfied with alignment or other procedure. Both hands with the palms forward are moved up and down at the sides of the body. When visibility is poor, a handkerchief is waved over the head or in a large circle.

6. **Pick up the instrument.** To avoid lost time the transitman should **never** pick up his instrument unless he is directed to do so by the chief. The signal is a quick upward motion with both hands palms up.

ESTABLISHING GRADE IN THE FIELD

234. Marking Elevations. Marking elevations is usually called **giving grade or grade staking.** It consists in setting marks like tops of stakes, nails in vertical surfaces, and keel marks at required elevations or setting marks at random elevations and indicating the vertical heights at which the future construction is to be built above or below them. Marks for grade are usually placed near the work and transferred to the work by carpenter's levels and rules. Sometimes they can be placed on the work itself.

235. Definitions. The word grade is used loosely in surveying parlance. In this text, **rate of grade** is used to mean the steepness of slope, and **grade** is used as the equivalent of **elevation of future construction.** The use of the word grade alone to mean slope is avoided.

236. Rate of Grade. The rate of grade is the rate of change of elevation expressed as a ratio of the change in elevation divided by the horizontal distance. For example, if a street sloped downward 1 foot in a horizontal distance of 100 feet, the rate of grate would be -0.01, or -1 per cent.

237. Cut and Fill. When the grade is above the grade mark, the notation **fill so many feet and inches** is written at the mark, thus, F 3′-6″; when below, **cut** is used, thus, C 1′-10″. The words fill and cut in this usage mean only up and down from a mark and have nothing to do with embankment or excavation.

238. Three Methods of Giving Grade. There are three methods of grade staking, here called **setting grade marks, shooting in grade,** and **indicating cuts and fills.**

239. Setting Grade Marks. The problem is to set a mark at a given grade. Starting at a bench mark, a line of levels is carried to the vicinity of the work. The instrument is thus brought into a position at a known H.I. from which the rod on the mark may be observed.

The **grade rod** (G.R.) is then determined. The grade rod is the reading on the rod that would be obtained from the present instrument position if the rod were placed on the required grade.

$$\text{G.R.} = \text{H.I.} - \text{grade}$$

The target is set at this value. If the top of a stake is to be used for a mark, it is driven down until, when the rod is placed upon it, the target

appears on the line of sight (see Fig. 17). The top of the stake is covered with keel and the station marked on the side. The letter G is often placed on the stake to indicate that the top is at grade.

240. When a grade mark is to be placed on a vertical surface, the rod is held against the surface and moved up and down until the target is on the line of sight. A mark or nail is then placed at the bottom of the rod (see Fig. 18).

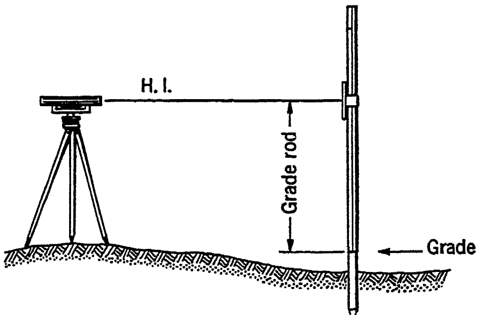


FIG. 17.—Setting a stake at grade

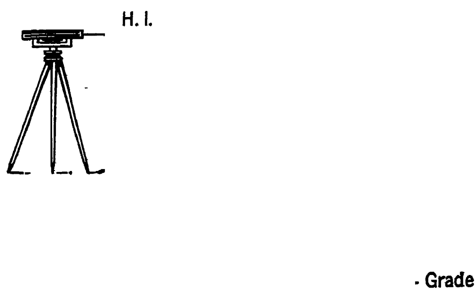


FIG. 18.—Setting a nail at grade.

241. Obviously, several grades can be set from one instrument position. The line of levels can then be carried to other locations and more grades set. Finally, the line of levels must be carried to the original or another bench mark for a check.

242. Setting Grades When No Support Is Available at the Proper Elevation. Very often no support is available in the vicinity of the work on which the grade can be marked. For example, the actual grade for a pipe line or for a platform cannot be marked on the ground. Under these circumstances it is customary to set grade stakes at a cer-

tain number of half feet above or below grade, the number of half feet used being often different at different stakes, and the stakes marked accordingly.

This is accomplished by setting the target at a certain number of half feet above or below the value of the grade rod. **If the grade-rod value is larger than the rod setting, the grade will be below the top of the stake by the difference.** In this case the stake will be marked cut, or C, so many feet. This may be stated as follows:

$$C = \text{G.R.} - \text{rod}$$

(where a negative value of C is taken as fill and marked F).

Thus, when the ground is not at the right height for setting a stake at grade the problem is to determine how many half feet to add to or to subtract from the grade rod so that a stake may be set.

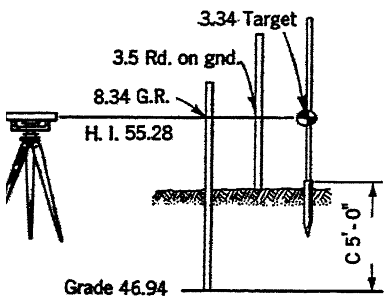


FIG. 19.—Setting a grade stake above grade.

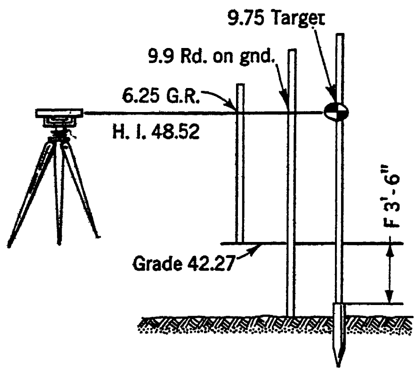


FIG. 20.—Setting a grade stake below grade.

After the grade rod has been computed, a rod is read on the ground where the stake is to be driven. Obviously, when the stake has been driven and a rod placed on it, the reading must be equal to or less than this value. Therefore, the proper number of half feet are chosen such that, when applied to the grade rod, a value will be obtained that is as near as possible equal to, yet less than, the reading when the rod is held on the ground.

Example 1 (see Fig. 19). The H.I. is 55.28; the grade is 46.94.

$$\text{G.R.} = 55.28 - 46.94 = 8.34$$

Accordingly, values like 7.34, 7.84, 8.34, 8.84, 9.34, etc., can be used.
The rod on the ground is 3.5.
Choose 3.34 as the nearest to 3.5 and yet less than it. Set the target at 3.34.

Compute

$$C = 8.34 - 3.34 = 5'0''$$

Example 2 (see Fig. 20). The H.I. is 48.52; the grade is 42.27.

$$\text{G.R.} = 48.52 - 42.27 = 6.25$$

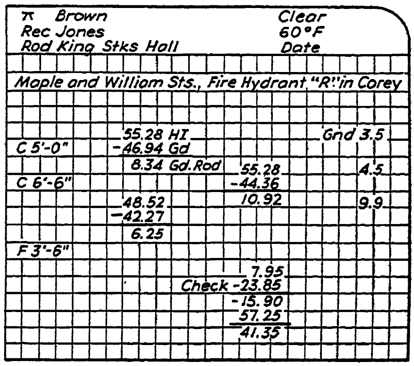
Accordingly, values like 5.25, 5.75, 6.25, 6.75, 7.25, etc., can be used.
The rod on the ground is 9.9.
Choose 9.75 as the nearest to 9.9 and yet less than it. Set the target at 9.75.
Compute.

$$C = 6.25 - 9.75 = -3'6'' \quad \text{or} \quad F = 3'6''$$

243. Procedure for Setting Grade Stakes. The following procedure is recommended for the method of setting grade stakes described above (see Fig. 21). Benchmark data, a list of required grades, and a sketch of the work must be taken into the field.

SMITH ST. GDS. FOR N. CURB

Sta	+	HI	−	Rod	Elev
BM*5	5.02	62.27			57.25
TP*1	0.27	55.28	7.26		55.01
0+0				3.34	51.94
1+0				4.42	50.86
TP*2	2.66	48.52	9.42		45.86
2+0				9.75	38.77
BM*6			7.17		41.35
	7.95		23.85		



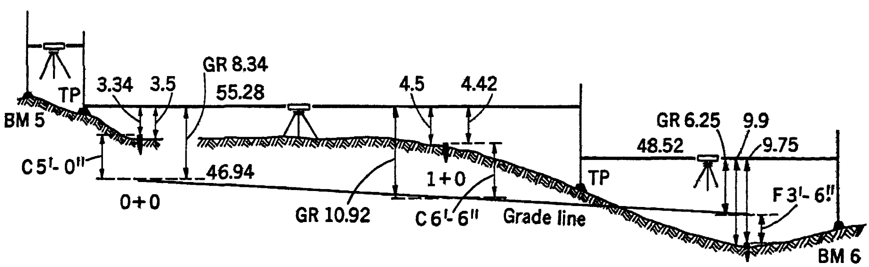


FIG. 21.—Field notes and procedure for setting grade stakes.

LIST OF GRADES

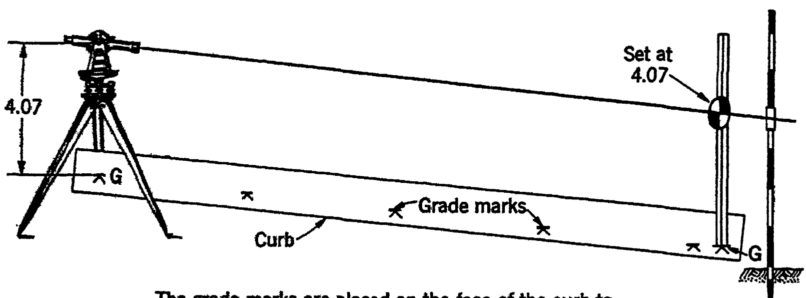
Station	Grade
0 + 0	46.94
1 + 0	44.36
2 + 0	42.27

1. By bench-mark leveling obtain an H.I. in the vicinity of the work, 55.28.
2. Compute G.R. on right-hand page of field notes, 8.34.
3. Take a rod on ground at stake location, and record on right-hand page, 3.5.
4. Set target at 3.34, and drive stake until, when rod is on stake, the target is on the line of sight.
5. Read rod through the target to check the target setting, and record in rod column, 3.34.
6. Compute elevation of stake, and record elevation in elevation column, 51.94.
7. Compute cut or fill by two methods as a check.

$$C = \text{G.R.} - \text{rod} = 8.34 - 3.34 = 5.00$$
$$C = \text{elev.-grade} = 51.94 - 46.94 = 5.00$$

8. Record cut or fill in feet and inches on right-hand page, and mark it on stake. Keel top of stake. If there is no cut or fill, mark the stake G.
9. Set any other grades possible from present H.I., or carry levels to another H.I., finally checking on B.M.

244. Shooting in Grade. When marks are to be set for a uniform rate of grade, computation and field work can be saved by a process known as **shooting in grade.**



The grade marks are placed on the face of the curb to indicate the grade of the gutter.
The marks labeled G are first established at an established grade by the usual method of setting grade marks.
The foresight shown consists of a piece of paper wrapped around a range pole and held by an elastic

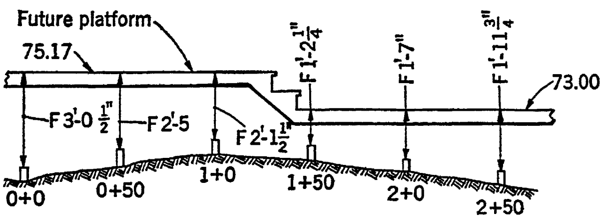
FIG. 22.—Shooting in a grade line.

This process is not independent. First it is necessary to set a grade stake or mark at each end of the uniform grade. A transit or level is then set up over the mark at one end (see Fig. 22). The difference in height between the instrument and the mark is measured (4.07), and the target on the rod is set at this value. The rod is held at the mark at the other end of the slope and the line of sight directed at it. This

places the line of sight parallel to the grade line at a known height above it. With this arrangement a grade mark can be set wherever desired by holding the rod at that point and raising or lowering the rod until the target is on the line of sight. The position of the foot of the rod is marked.

A foresight on the line of sight should be established if many grade marks are to be set. When only a few are necessary, the slope of the line of sight should be checked when the work is completed by holding the rod at the original mark and making sure the line of sight strikes the target.

245. Giving Grade by Indicating Cuts and Fills. The most rapid and in many ways the best method of giving grade is to indicate



Sta.	Elev.	Grade	Elev.-Grade	C or F
0+0	72.13	75.17	−3.04	F 3'-0½"
0+50	72.75	75.17	−2.42	F 2'-5
1+0	73.05	75.17	−2.12	F 2'-1½"
1+50	71.81	73.00	−1.19	F 1'-2¼"
2+0	71.42	73.00	−1.58	F 1'-7
2+50	71.02	73.00	−1.98	F 1'-11¾"

FIG. 23.—Giving grade by indicating cut or fill.

the cuts or fills measured from convenient objects near the work. Usually the tops of the line stakes or other line marks are used.

The elevations of the tops of the line stakes or the objects chosen are determined by profile leveling. The values of the cuts or fills are computed by comparing the elevation of each mark with the grade at that particular position. They are computed in hundredths of a foot, reduced to inches and marked on the stakes or near the marks (see Fig. 23). The tops of the stakes or other objects are usually covered with keel to indicate that grade should be measured from those points.

246. Reducing Hundredths to Inches. One inch equals 8⅓ hundredths of a foot. The quarters of a foot can be expressed exactly in both hundredths and in inches. By adding or subtracting 8 to or from the nearest quarter point the inch values in hundredths of a foot can be computed within ⅓ of a hundredth. These values should be computed and memorized, thus:

In.	Quarter points	Computations	In. values, hundredths of a ft
0	0		0
1		0 + 8	8
2		25 − 8	17
3	25		25
4		25 + 8	33
5		50 − 8	42
6	50		50
7		50 + 8	58
8		75 − 8	67
9	75		75
10		75 + 8	83
11		100 − 8	92
12	100		100

To reduce hundredths to inches, choose the nearest inch value and correct for the odd hundredths by calling them eighths of an inch. Thus,

$$0.89\text{ ft} = 0.92\text{ ft} - 0.03\text{ ft} = 11\text{ in.} - \tfrac{3}{8}\text{ in.} = 10\tfrac{5}{8}\text{ in.}$$
$$0.44\text{ ft} = 0.42\text{ ft} + 0.02\text{ ft} = 5\text{ in.} + \tfrac{2}{8}\text{ in.} = 5\tfrac{1}{4}\text{ in.}$$
$$0.71\text{ ft} = 0.75\text{ ft} - 0.04\text{ ft} = 9\text{ in.} - \tfrac{4}{8}\text{ in.} = 8\tfrac{1}{2}\text{ in.}$$

The error is never greater than 0.005 foot.

247. Signals for Setting Grade Marks. The only signals used for giving grade that are not used for profile leveling are "up" and "down." Up is signaled by moving the hand upward from shoulder height, usually with the index finger pointed up. Down is signaled by lowering the hand from waist height, with the index finger pointed down. Large slow motions indicate large amounts, and vice versa. Usually the estimated distance is signaled immediately afterward in hundredths of a foot.

ALIGNMENT IN THE SHOP

248. Shop Practice. The use of surveying instruments in the shop is as varied as the ingenuity of the production engineer. Standard practices have not been developed so that only usual operations can be outlined here. The very short sights used make it possible to work to thousandths of an inch instead of hundredths of a foot, but they impose certain restrictions.

249. When short sights are used, the objective lens must be moved comparatively long distances in focusing. If this movement (which is guided by the objective slide) is not exactly parallel to the line of sight, errors will result (see Fig. 25). The error can be measured and neutralized by reversal.

FIG. 24.—Berger instruments in use at a Douglas plant. (*C. L. Berger & Sons, Inc. and Douglas Aircraft Co.*)

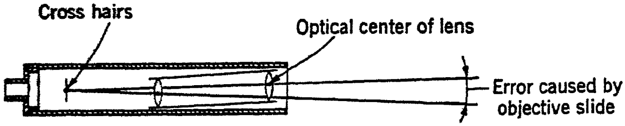


FIG. 25.—The objective-slide error.

250. The plumb bob does not indicate the precise position of the vertical axis or the line of sight. When accuracy is desired, the line of sight itself must be placed on line by observing two points on line and moving the instrument accordingly.

251. Alignment of Targets. Most alignment work involves observing from a distance of a few feet. A thousandth of an inch can be easily seen at that distance. Usually steel scales graduated to hundredths of an inch are used instead of special devices. They should be kept bright and be well lighted.

252. Shop Methods for Alignment. Dimensions on drawings are nearly always given in the form of distances from three mutually per-

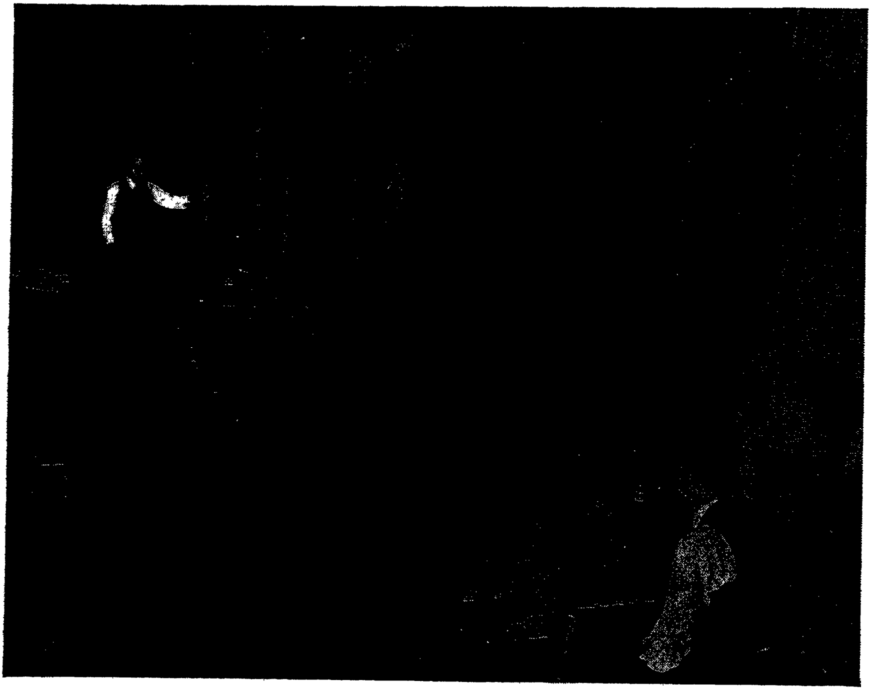


FIG. 26.—Designing a suspension bridge by measuring the deflections of a model with a Y level at the Trenton plant of the John A. Roebling's Sons Co. (*John A. Roebling's Sons Co.*)

pendicular planes. Surveying instruments can accurately establish horizontal and vertical planes. The usual procedure therefore is to arrange the work so that the dimension planes are vertical and horizontal, either by adjusting the work according to the instrument or by placing the work nearly in position and establishing these planes on the work for the first time with the instrument.

253. Shop Leveling. It is usually more accurate and quicker to arrange the work so that the first operation is leveling. One of the dimen-

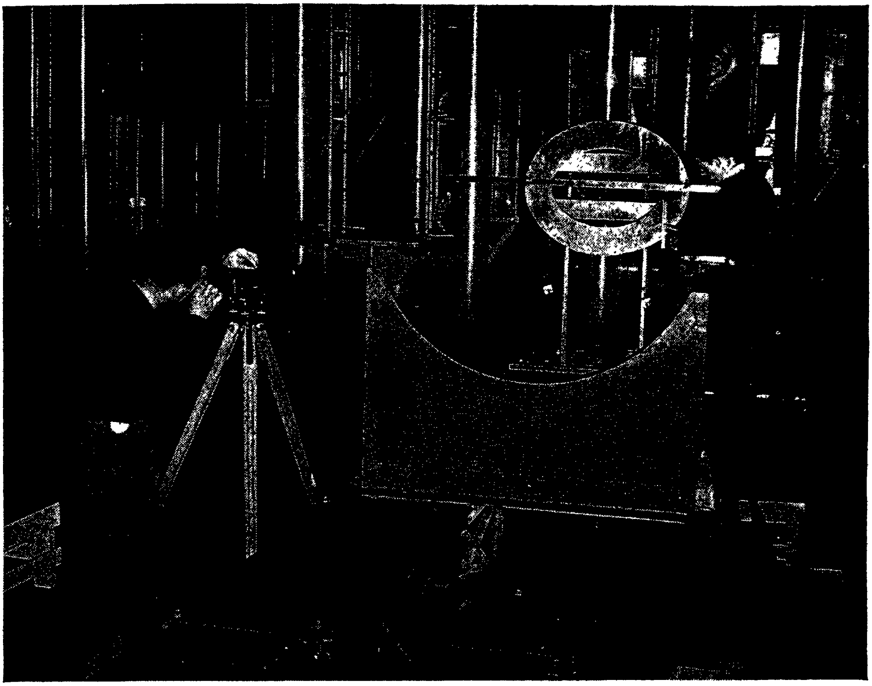


Fig. 27.—Leveling a fixture. A Y level manufactured by the Eugene Dietzgen Co. of Chicago being used to level an airplane fixture at the Hagerstown, Md., plant of the Fairchild Engine & Aircraft Corp. (*Eugene Dietzgen Co. and Fairchild Engine & Airplane Corp.*)

sion planes must usually be made horizontal, and it is more accurate to set a plane horizontal with a level than to achieve the same result by setting two other planes vertical with a transit.

254. The level should be placed approximately on the perpendicular bisector of the longest horizontal center line of the work. This tends to equalize the lengths of the sights and thus to increase the accuracy.

255. Leveling the Work. At least three widely separated points are chosen, usually machined surfaces or scribed lines. A rule is held

at these points, and the vertical readings are taken directly on the scale by the levelman. The work must be adjusted until such differences in elevation are obtained that the dimension plane will be level. When high accuracy is desired, the level should be placed at a corresponding location on the opposite side of the work and the readings checked (see Fig. 28). Any difference should be balanced out by adjusting the work. This process eliminates the errors of the slide and any error in adjustment.

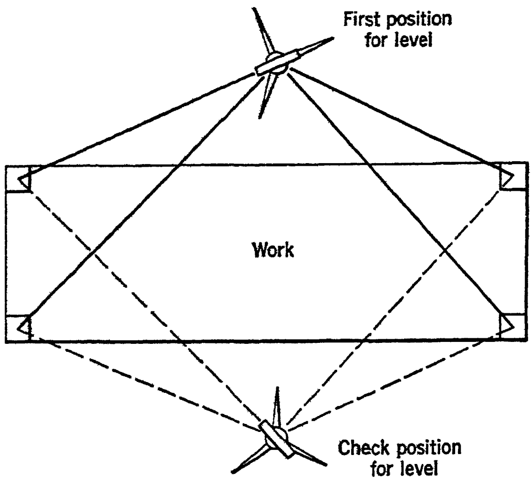


FIG. 28.—Shop leveling.

256. When the work has been leveled, the desired vertical measurements can be made by measuring from the line of sight.

257. Setting the Level at a Required Height. Frequently, it is desirable to set points exactly on the line of sight. This requires adjusting the level to the required elevation, a movement which can be accomplished by adjusting the spread of the tripod legs or adjusting the legs themselves if an adjustable tripod is available. Special elevators can be made (see Fig. 1, Chap. I) that facilitate this operation by raising and lowering the instrument without throwing it much out of level.

258. Whatever device is used, however, the process is essentially one of cut and try. The level must be raised to the estimated position and leveled, and the elevation tested by sighting. If the height is not correct, the process must be repeated.

259. Alignment with the Transit. The usual transit alignment problem is to establish a vertical plane in a given direction. For accurate results, as explained previously, the line of sight itself must be placed in line. The procedure is as follows: Two points are chosen along the greatest dimension of the work, and preferably at nearly the same height.

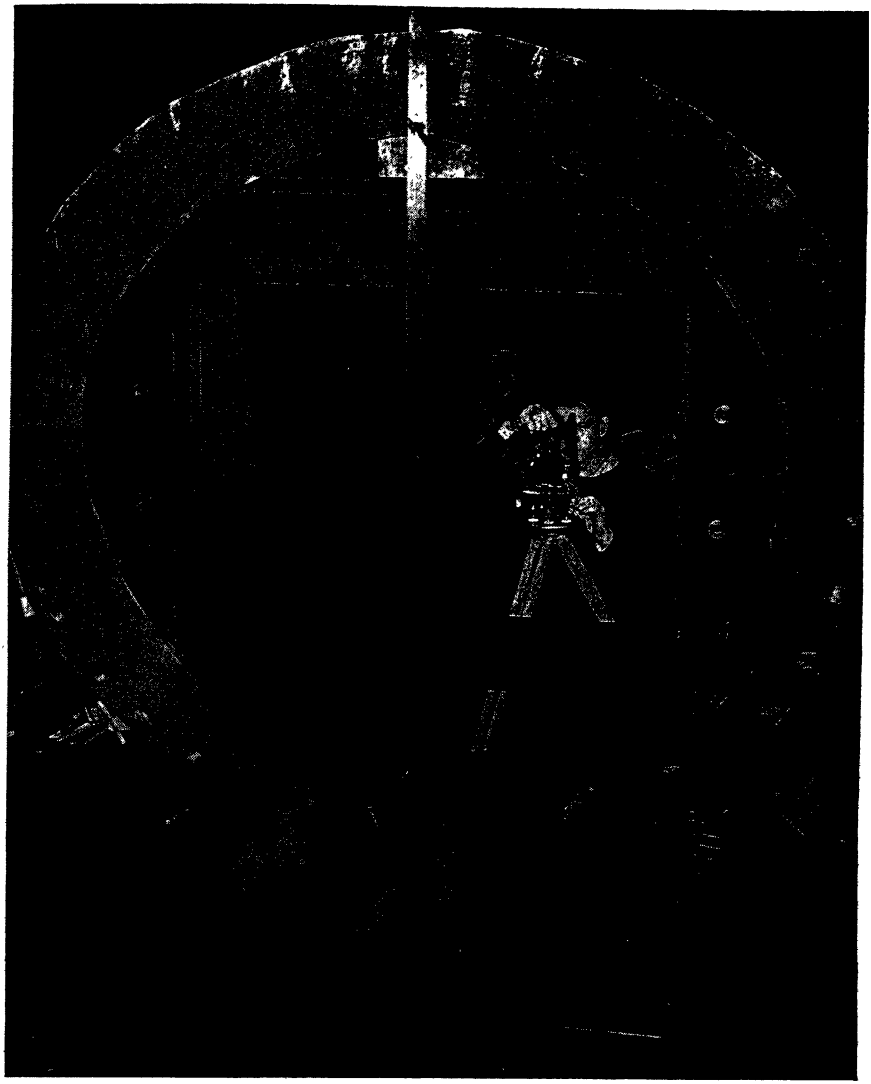


FIG. 29.—Establishing a center line. Centering a fuselage fixture with a transit manufactured by the Eugene Dietzgen Co. of Chicago at the Hagerstown, Md., plant of the Fairchild Engine & Airplane Corp. (*Eugene Dietzgen Co. and Fairchild Engine & Airplane Corp.*)

The instrument is set up as nearly as possible in the plane desired, with the telescope nearly at the elevation of the points chosen. The instrument is pointed parallel to the desired plane by estimation, and readings of a scale are taken on the two points. The direction of the instrument is changed until the proper difference between the two readings is obtained. This places the line of sight in a plane parallel to the desired vertical plane (see Fig. 30).

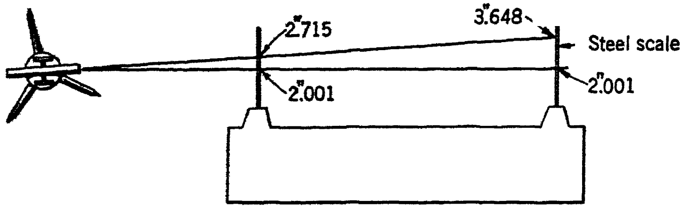


FIG. 30.—Aligning transit with two gauge points.

260. If high accuracy is desired, the transit should be set up using the telescope level and the reading should be made direct and reversed. The average readings are used. This process eliminates the errors of the slide and all transit adjustment errors.

261. When the transit is properly oriented, horizontal dimensions left and right can be established by reading the scale directly from the instrument.

262. Placing the Transit Plane on a Desired Line. It is often desirable to place the plane established by the transit along a certain line. In this case the procedure is the same except that instead of changing the direction of the line of sight the instrument is moved laterally until the two desired readings are obtained (see Fig. 32). This is known as **wiggling in.** It can be accomplished by shifting the leveling head. Since this requires releveling the transit each time, it is a slow procedure. Special shifting devices can be used (see Fig. 36) that prevent throwing the instrument much out of level and control the lateral movement.

263. Setting Up over or under a Point. It is clear that both in leveling and alignment it is more difficult to establish a **certain** desired plane than to establish a plane **parallel** to the desired plane. When the accuracy desired is not quite so great, it is possible to place the vertical axis of the transit in the plane at the start by setting up over or under a point in the plane.

264. A well-made plumb bob and a thread instead of a string must be used to reduce errors of setup. The thread must be attached to the bob at the center line. The bob and the attachment of the thread can be tested by rotating the bob when hung over a point. If the point of

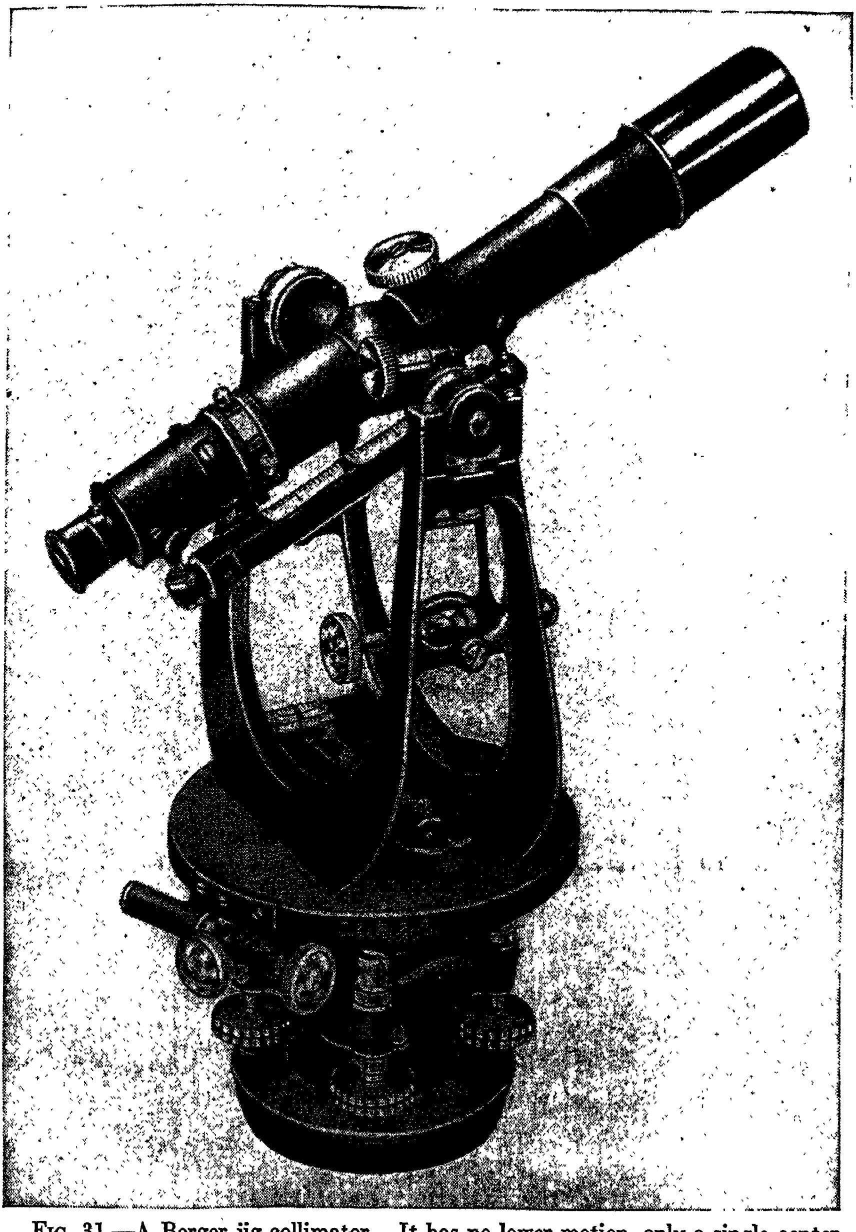


FIG. 31.—A Berger jig collimator. It has no lower motion, only a single center, no compass, and no verniers. It is especially designed for accurate jig alignment. (*C. L. Berger & Sons, Inc.*)

the bob does not wobble, it is accurate. The plumb-bob attachment to the transit can be tested by noting whether or not the bob remains over a point when the cap supporting the hook chain is slightly unscrewed. The bob point should not move throughout one revolution of the cap.

265. At the top of the telescope on most transits is a small center mark, which is on the line of the vertical axis when the telescope is perpendicular to the axis. By using this mark the transit can be set up under a plumb bob.

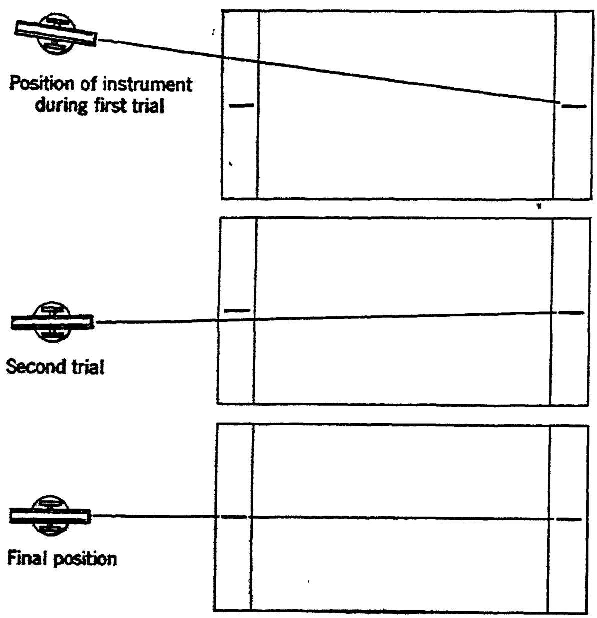


FIG. 32.—Wiggling in.

266. The only point in an instrument that remains stationary while it is being leveled is the center of the ball-and-socket joint. Therefore, both the plumb bob and the center mark on the telescope move laterally during leveling. To make an accurate setup the transit should be leveled and then checked for position. If it is not on the point, it must be shifted laterally and again leveled and checked (see Fig. 33).

267. Establishing an Angle. A horizontal angle is established by ordinary surveying methods. If it is desirable not to set up at the vertex, the desired plane can be established by offsets. The angle should be checked with the telescope reversed. When two or more angles are established from the same line, a long backsight should be used.

268. Tripods and Other Devices for Mounting Instruments. In shop alignment work the instrument must often be stationed at various elevations, from close to the floor to high above it. Tripods having adjustable legs should always be used. A tripod fitted with specially

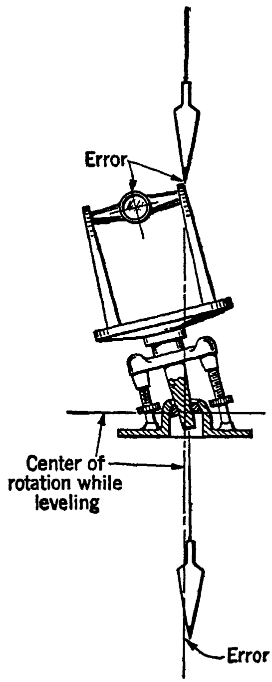


FIG. 33.—Position of transit when not level. Unless a transit is level it cannot be set up precisely over or under a point.

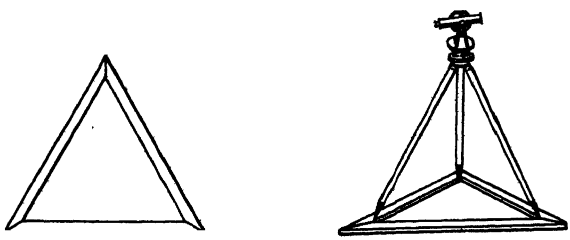


FIG. 34.—Wooden triangle for masonry floors.

made, very short legs will be found useful. An arrangement of three boards in the form of a triangle (see Figs. 34, 35) should be available when numerous setups are made on masonry or wood. The tripod legs are placed in the corners but rest on the floor. The floor will hold the

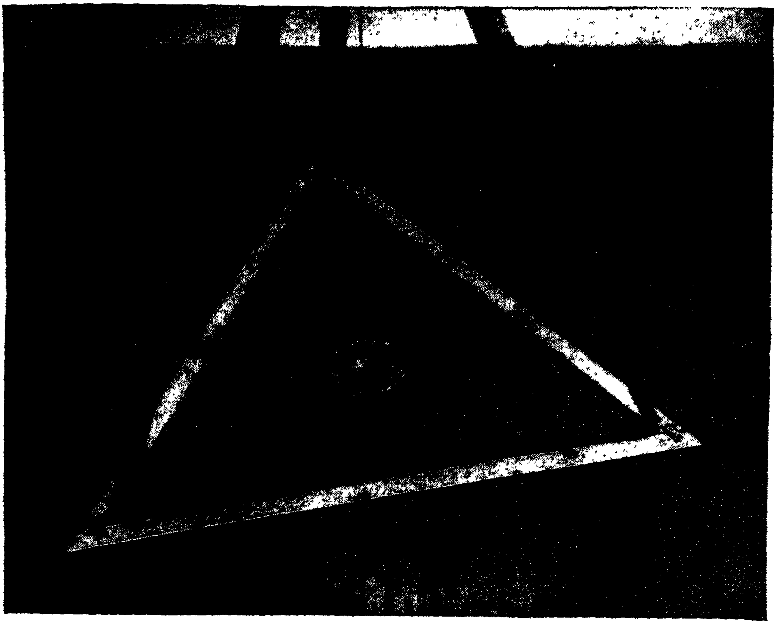


FIG. 35.—Floor triangle in use.

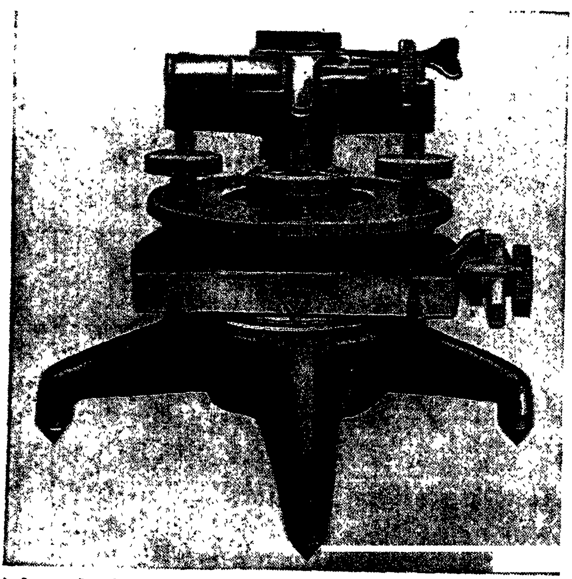


FIG. 36.—A lateral adjuster screwed to a trivet. (*C. L. Berger & Sons, Inc.*)

instrument steady, and the triangle will prevent the tripod legs from slipping.

269. Trivets (see Fig. 36) are designed to support the instrument within a few inches of the floor. They have three very short fixed legs, and at the top is an instrument mount on which the instrument can be screwed. Some instrument manufacturers provide three studs that can be screwed into the underside of the base that supports the instrument in its case. The base can be removed from the case, the studs inserted, and the base used as a trivet. When these bases are made of wood,

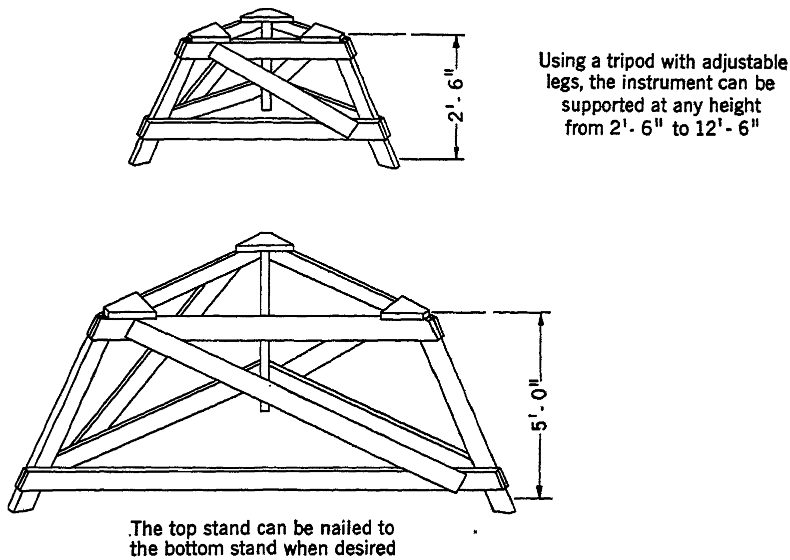


FIG. 37.—Set of stands.

three wood screws can be screwed into the underside and filed to a point to serve in place of the studs.

A special type of instrument mount is available that will screw into heavy timbers. It is called a **bracket.**

270. Rigidity of Support. Support of the instrument mount must be arranged so that the instrument is not affected by movements of the observer or by other movements. Masonry or earth floors usually provide such support, but wooden floors seldom can be used without precautions. A support is acceptable if the telescope bubble remains stationary after being leveled, when the observer moves around the instrument, or when the usual movements occur in the vicinity.

271. Frequently a wooden floor can be used if the observer stands on a board that rests on supports near the bearing walls.

272. When the instrument must be raised above the floor, it is nearly always necessary to arrange an entirely separate support for the observer. Stands designed to elevate the instrument must have three legs to provide rigidity. A useful set of stands is shown in Fig. 37. By proper arrangement they will support the instrument at any height usually required. The observer, of course, must have a separate support.

EXAMPLES OF FIELD METHODS

273. Batter Boards. When the engineer has set marks for line and grade, it is often necessary to use string or wire to guide the actual

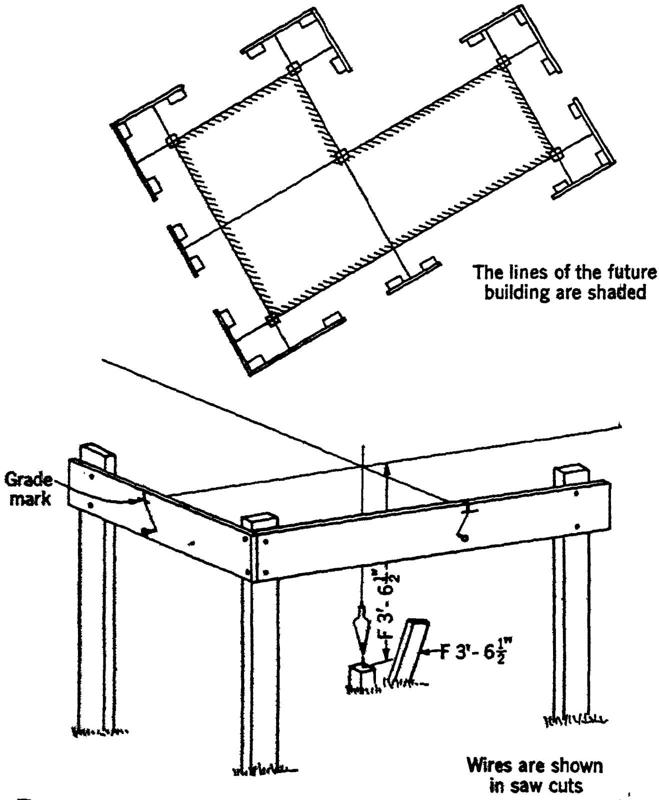


FIG. 38.—Batter boards and wires in place over original stakes.

construction. These are usually supported on pins or **batter boards** (see Figs. 38, 39).

274. The method of using batter boards for buildings has become standardized. They are usually so designed that they will support the

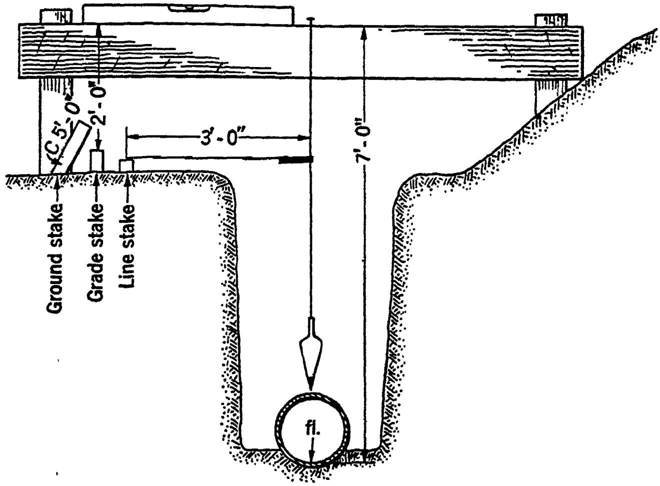


Fig. 39.—Batter board for pipe line.

string or wire so that it marks the exterior face of the building and also the elevation of the first floor. The exterior face of a building is a technical term. Figure 40 illustrates various building faces.

275. Sometimes the engineer indicates the fill from each corner stake up to the first-floor elevation. In this case the contractor adjusts the wire, using a plumb bob to set the alignment and a rule to measure up from the stake. Sometimes line marks are transferred from the stakes

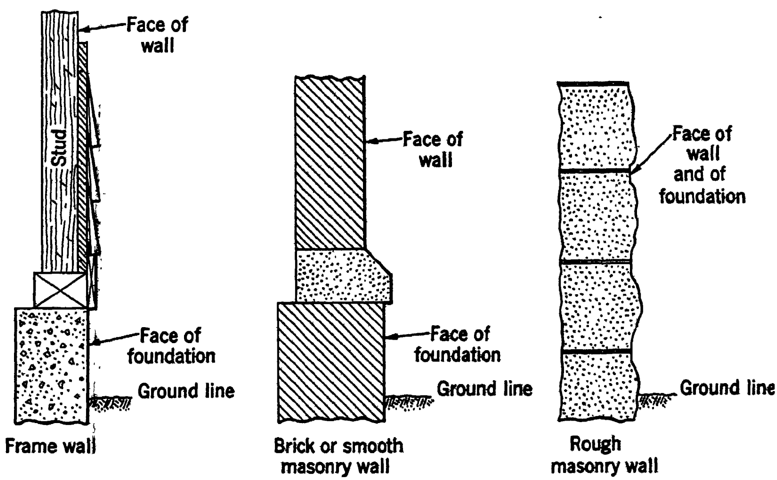


Fig. 40.—Typical walls. Measurements to buildings are made to face of wall or to face of foundation and so noted.

to the batter boards with a transit, and the grade of the first floor is marked directly on the batter boards (see Fig. 38).

276. Drainage Terms. Certain technical terms are used in connection with drainage facilities. **Flow line** is the bottom inside of a drainage pipe. **Invert** is the bottom inside of a drainage channel. Drainage manholes usually contain drainage channels (see Fig. 41). Inverts are sometimes also called flow lines. Flow lines and inverts are the lines always used in referring to elevations and alignment for drainage. They are often abbreviated to f.l. and Ivt.

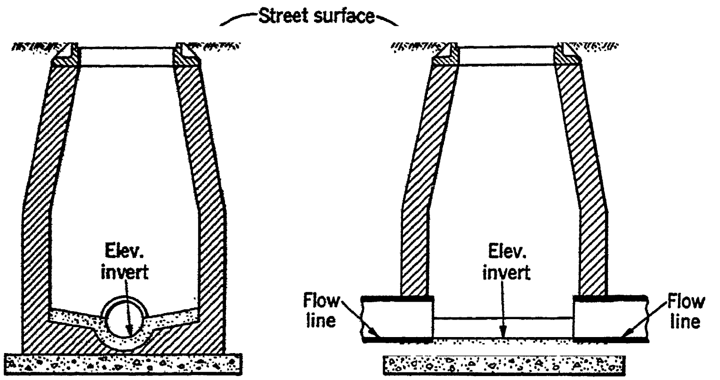


FIG. 41 —Cross sections of a typical manhole showing invert and flow line.

277. Field Location. Often a project is so simple that the entire engineering process can be carried out in the field. The reconnaissance, preliminary survey, map, plan, and location survey can be executed in a few hours. The process is illustrated by the following problems.

278. Problem of Field Location. Suppose it is necessary to build a branch drain from a house to the main street drain. It is assumed that the f.l. must be at least 3 feet below the ground surface to prevent freezing. The minimum rate of grade of the f.l. should be 0.004. No breaks in rate of grade or direction should occur except at manholes, for sediment collects at such points.

279. Figure 42 illustrates the problem. The elevation of the flow line at the house as indicated on the architect's plan is 70.03, and a connection already exists at the street manhole as shown by the city records. The elevation of the connection must be determined during the preliminary leveling by opening the manhole cover and observing a rod held on the flow line.

280. Outline of Method. It is evident at once from the reconnaissance that the line can be straight. An investigation by a preliminary survey must be made to determine whether or not a straight grade line can be used without bringing the flow line too near the surface. A profile of the ground is run and plotted (see Fig. 43). This constitutes the map. On this profile, a straight line representing a possible

flow line is drawn from the known elevation (70.03) of the flow line at the house to any point not below the manhole connection (60.52). It is discovered that such a line comes too near the ground. Other flow lines are tried with various locations and elevations for breaks in rate of grade, the object being to find an arrangement that complies with the specifications and requires a minimum quantity of excavation and number of manholes. In this case a break in the rate of grade of the flow line located at about Station 2 + 30 at an elevation of about 62.1 (as indicated by scaling) will solve the problem. It will require one new manhole (at 2 + 30). The existing connection at the street manhole can be used. Its f.l. elevation is 60.52.

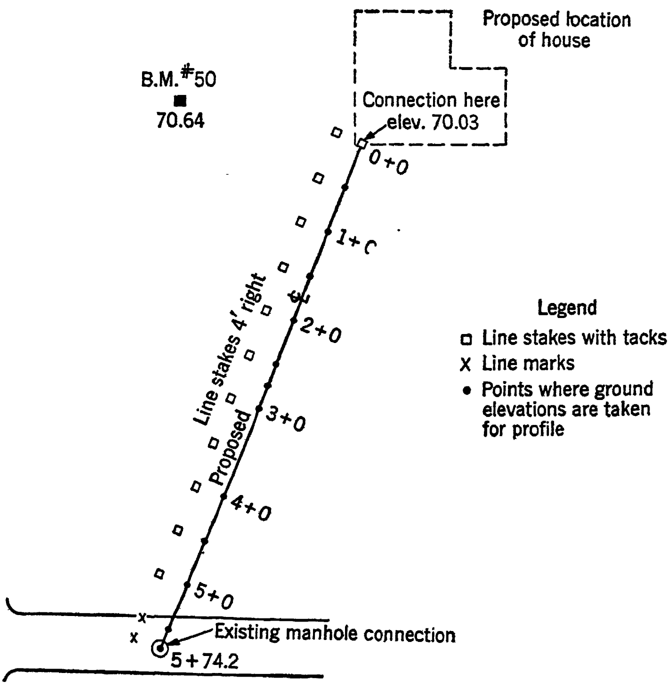


FIG. 42.—Plan showing example of field location.

It is now necessary to compute grades for the intervening points. The grades must be such that they will produce absolutely straight slopes for the flow line. For this purpose an **exact** position and elevation must be assumed for the invert of the new manhole Accordingly, Station 2 + 30 and elevation 62.10 are chosen, and the grades are computed by proportion. This completes the plan (see Fig. 43).

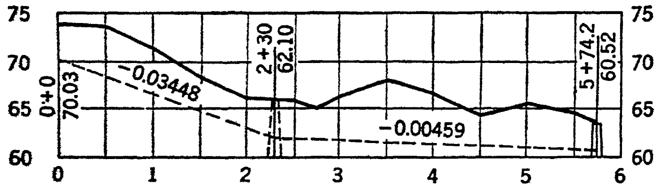
It is decided to give grade by indicating the cut from the top of the line stakes. It is to be remembered that cut is the distance from the top of the line stakes down to the flow line. It is **not** the excavation, which would be the distance from the ground down to the bottom of the trench.

To indicate cuts, the elevations of the tops of the line stakes must be found by leveling and the individual cuts computed by subtracting the required grades.

It is also decided to place the line stakes at a 4-foot offset to prevent disturbance when the trench is excavated.

With the above in mind, the procedure (the location survey) is planned to require a minimum of field work.

281. Field Procedure for Field-location Problem. The field steps are the following:



Profile drawn in field book

Computations of Grades

	Sta	Grade
Start	0 + 0	70.03
End	2 + 30	62.10
Diff	230	− 7.93

Rate $\dfrac{-7.93}{230} = -.03448$

Changes in grade = Dist. × Rate

50 (−.03448) = 1.724
30 (−.03448) = 1.034

	Sta	Grade
Start	2 + 30	62.10
End	5 + 74.2	60.52
Diff	344.2	− 1.58

Rate $\dfrac{-1.58}{344.2} = -.00459$

Changes in grade

20(−.00459) = .092
50(−.00459) = .230
24.2(−.00459) = .111

Sta	Grade	Grade Used
0 + 0	70.03	70.03
	− 1.724	
+ 50	68.306	68.31
	− 1.724	
1 + 0	66.582	66.58
	− 1.724	
+ 50	64.858	64.86
	− 1.724	
2 + 0	63.134	63.13
	− 1.034	
+ 30	62.10	62.10
	− .092	
+ 50	62.008	62.01
	− .230	
3 + 0	61.778	61.78
	− .230	
+ 50	61.548	61.55
	− .230	
4 + 0	61.318	61.32
	− .230	
+ 50	61.088	61.09
	− .230	
5 + 0	60.858	60.86
	− .230	
+ 50	60.628	60.63
	− .111	
+ 74.2	60.52	60.52

FIG. 43.—Design of grades for field location.

1. Stake out a 4-foot offset line, placing stake 0 + 0 beside the point in the house where the house connection is located and a stake every 50 feet thereafter. Carry the measurement to a point beside the manhole, and determine its plus.

2. Find the elevation of the ground at each 50-foot point along the true line and at all breaks in ground slope. The rod is held on the ground at an estimated 4 feet from and opposite to each offset stake. This places the rod at the true position on the construction line. The rod is read to tenths.

3. At the same time determine the elevation of the tops of each of the offset-line stakes.

HOUSE CONNECTION

Chief Smith H.C. Cole Fair
π Jones R.C. Doe 60°
Date

Sta	+	HI	−	Rod	Elev	Grade	Cut	Mark Stk.
BM#50	6.78	77.42			70.64	Nail in	Maple	Near House
0+0 S				3.15	74.27	70.03	4.24	C 4'-2 7/8"
G				3.2	74.2			
+50 S				4.00	73.42	68.31	5.11	C 5'-1 3/8"
G				4.5	72.9			
1+0 S				5.41	72.01	66.58	5.43	C 5'-5 1/8"
G				6.0	71.4			
+50 S				9.15	68.27	64.86	3.41	C 3'-4 7/8"
G				9.3	68.1			
2+0 S				11.04	66.38	63.13	3.25	C 3'-3"
G				11.1	66.3			
TP#1	4.03	70.50	10.95		66.47			
+50 S				4.39	66.11	62.01	4.10	C 4'-1 1/4"
G				4.5	66.0			
+75 G				5.5	65.0			
3+0 S				4.07	66.43	61.78	4.65	C 4'-7 7/8"
G				4.1	66.4			
+50 S				2.35	68.15	61.55	6.60	C 6'-7 1/4"
G				2.5	68.0			
4+0 S				4.18	66.32	61.32	5.00	C 5'-0"
G				4.1	66.4			
+50 S				6.13	64.37	61.09	3.28	C 3'-3 3/8"
G				6.2	64.3			
5+0 S				5.22	65.28	60.86	4.42	C 4'-5"
G				5.2	65.3			
+50 S				5.90	64.60	60.63	3.97	C 3'-11 5/8"
G				5.9	64.6			
+74.2 S				6.90	63.60			
G				6.9	63.6			
Connect				9.98	60.52			
TP#2	5.89	72.92	3.47		67.03			
BM#50			2.29		70.63			
BM#50	7.42	78.06			70.64			
2+30 S				11.81	66.25	62.10	4.15	C 4'-1 3/4"
BM#50			7.42		70.64			

Fig. 44.—Field notes for field location.

4. Draw the profile of the ground elevations, and determine the grade profile for the flow line.

5. Compute the cuts, and mark the stakes.

6. Measuring along the offset line, place a stake for the new manhole, find the elevation of the top of the stake set, and mark the cut for the invert.

The form of notes is shown in Fig. 44.

PROBLEMS

1–2. Compute the grades for each half station for a uniform rate of grade between the positions indicated.

1 Sta.	1 Grade	2 Sta.	2 Grade
0 + 00	29.68	7 + 36.3	47.21
6 + 73.41	34.25	12 + 40.9	25.82

3. Convert the following feet and decimals into feet and inches:

2.69	6.08	1.83
4.79	5.60	0.36
8.21	3.87	9.27
7.93		

4–5. Write out the form of notes with consistent numbers for giving grades by indicating cuts and fills on existing stakes for the following:

4

Sta.	Grade	Elev. mark
0 + 0	29.38	26.32
0 + 50	↑	24.46
1 + 0		29.22
1 + 50		27.36
2 + 0	+4%	35.42
2 + 50	Uniform	31.48
3 + 0	slope	27.17
3 + 50		28.16
4 + 0	↓	31.50
4 + 50	47.38	32.28

5

Sta.	Grade	Elev. mark
0 + 0	91.29	90.22
0 + 50	↑	90.26
1 + 0		87.47
1 + 50		93.49
2 + 0	−3%	92.75
2 + 50	Uniform	88.29
3 + 0	slope	85.36
3 + 50		85.61
4 + 0	↓	87.81
4 + 50	77.79	89.20

6–7. Write out the form of notes with consistent numbers for setting grade stakes at a certain number of half feet above or below grade as in Fig. 21 for the following:

6

H.I.	Sta.	Grade	Rod on ground
37.28	0 + 0	32.61	8.2
	0 + 50	33.01	5.4
	1 + 0	33.41	2.3
	1 + 50	33.81	1.7
39.46	2 + 0	34.21	3.5
	2 + 50	35.61	4.7
	3 + 0	36.01	5.6
	3 + 50	36.41	7.2
	4 + 0	36 81	9.7
	4 + 50	37.21	10.6

7

H.I.	Sta.	Grade	Rod on ground
81.29	0 + 0	80 32	1.4
	0 + 50	81.32	0.1
	1 + 0	82.32	0.6
	1 + 50	83.32	1.7
	2 + 0	84.32	1.9
92.42	2 + 50	85.32	2.8
	3 + 0	86.32	3.2
	3 + 50	87.32	4.2
	4 + 0	88.32	6.7
	4 + 50	89.32	7.8

CHAPTER XII

MISCELLANEOUS OPERATIONS

282. Supplementary Operations. The preceding chapters cover the bare essentials of instrument operation and surveying methods necessary for precise surveys of limited extent. Certain standard operations, however, so facilitate the work that without them it is difficult, if not impossible, successfully to carry out a survey project. These standard operations are covered in this chapter under the following four headings: **Elementary Triangulation, Ties to Horizontal Control, Traverse and Alignment Operations, Obstacles to Line and Levels.**

ELEMENTARY TRIANGULATION

283. The Use of Elementary Triangulation. While triangulation is the most important means of establishing horizontal control over large areas, it is not an important factor in surveys of limited extent. A simple system of a few well-placed triangles will often, however, greatly increase the over-all accuracy of the traverse net with a minimum expenditure of time and labor (see Fig. 1).

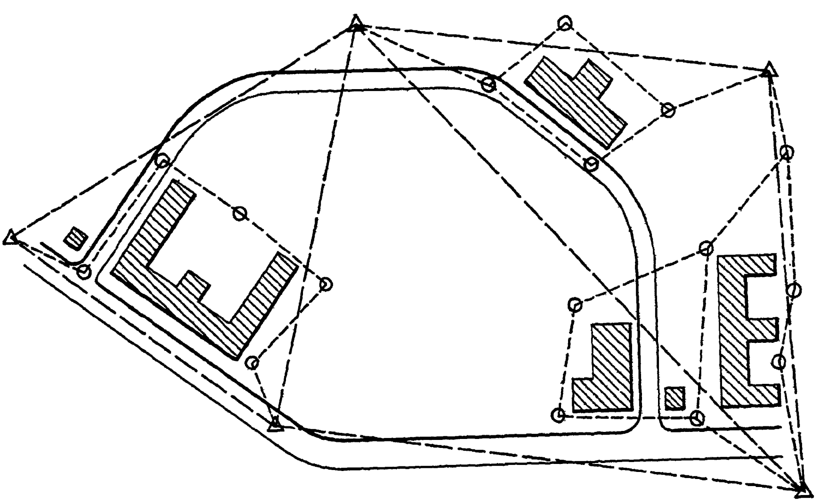


FIG. 1.—Survey for plant expansion showing the scheme of triangulation and traverse stations.

284. There are many types of triangulation schemes and methods of computing the coordinates they establish. Figure 2 shows a system of single triangles, and Fig. 3 shows other types. The system of single triangles only will be described, for the other types require methods of adjustment beyond the scope of this text.

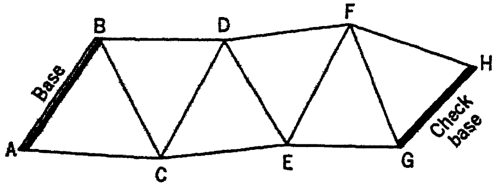
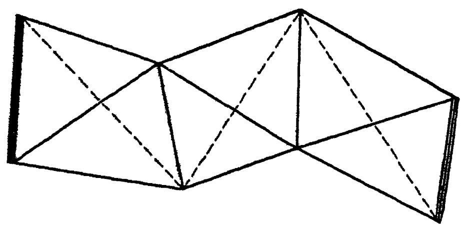
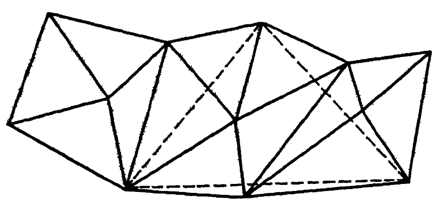


FIG. 2.—System of single triangle.



System of overlapping triangles in quadrangles. If the dotted lines are omitted this becomes a system of single triangles



System of central point figures with an overlapping triangle

FIG. 3.—Other systems of triangles.

285. A System of Single Triangles. The triangulation stations should be placed around the exterior of the area to be surveyed. They are arranged so that the triangles formed are as nearly equilateral as possible to give the maximum strength and hence the most accurate results. A minimum of two sides of the system is measured to serve as a base and a check base as indicated in Fig. 2, by AB and GH. All the angles are measured and station adjustments completed.

286. The resulting angles are then adjusted so that the sum of the angles in each triangle equals 180 deg. Equal increments are applied to the three angles of each triangle to obtain this adjustment.

287. The lengths of the sides are computed by the sine formula, beginning with the length of the longest base *AB*. This will result in a computed as well as a measured length for the check base *GH*. If these two values check within the accuracy desired, the results can be allowed to stand. If desired, all the computed lengths of the sides can be increased or decreased by the same ratio (or by adding or subtracting a small logarithmic increment) so that the final value of the check base will be about the average of the original computed value and the measured length.

288. The bearing of one of the sides is assumed or determined and the other bearings are computed by using the adjusted angles. The station coordinates are computed by the methods used for traverses. As the figure is geometrically consistent after adjustment, any route through the triangles will give the same results.

289. When the coordinates of the triangulation stations have been computed they are thereafter held fixed. All traverses tied to them are adjusted to close on them as described under Connecting Traverse in Chap. VII.

TIES TO HORIZONTAL CONTROL

290. Purpose of Horizontal Ties. To make a map or plan or to determine accurately the relative position of a number of points, a horizontal control system must be established by triangulation or traverse, as described in previous chapters. This results in a number of stations whose positions are known (see Fig. 1). The problem remains to decide what survey measurements should be made to connect the objects to be located with the system of stations. The decision depends on the field conditions, the accuracy desired, and the ease of plotting or computing the results.

291. Polar Coordinates. For many reasons, one method is the best for conditions usually encountered. It consists in measuring the distance and direction to the object from the most convenient station.

292. The distance is measured with a steel tape if accurate results are desired. If these data are to be used for plotting a map, **a metallic tape** (see Fig. 13, Chap. II) or the **stadia method** described in a later chapter (see Arts. 328 ff.) will suffice.

293. The direction is determined with a transit. It is set up over the station from which the distance is measured, and the angle is measured between the direction of a second station and the direction of the object. By using the azimuth of the second station and the measured angle, the

azimuth of the object can be computed if desired. Often the direction is not computed, for the angle can be laid out on the map directly with a protractor. It is more convenient to plot by azimuths than by angles from various lines. For this reason the transit is usually **oriented** so that the circle gives azimuths directly. By using the upper motion, the *A* vernier is set at the azimuth of the **station** at which the line of sight **will be pointed.** By using the lower motion, it is then pointed at that station. When the upper motion is used thereafter, the *A* vernier will

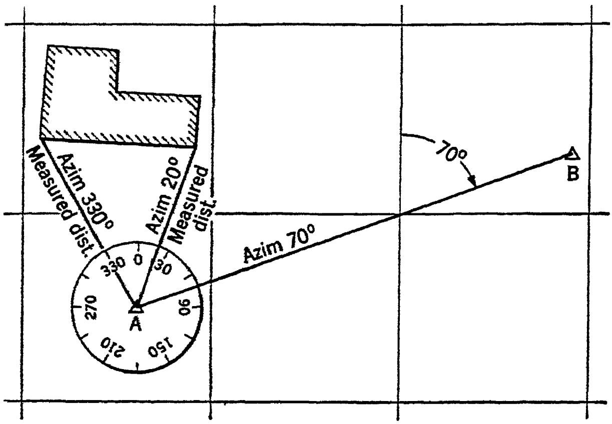


FIG. 4.—Orientation of transit. The transit is at station *A*. It is oriented by sighting station *B*. When it is oriented the azimuths can be read directly from the graduated circle.

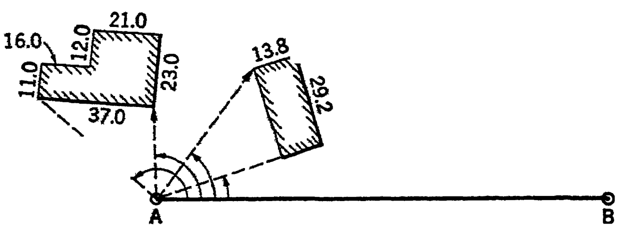


FIG. 5.—Angle and distance measurements.

read the azimuth of the line of sight. Accordingly, the various objects are pointed by using the upper motion and their azimuths are read on the *A* vernier (see Fig. 4). Before picking up the transit, a check sight is taken on the station used for orienting, to make sure that the lower motion has not been used inadvertently after orienting.

294. The angular accuracy of this method is of course not much better than ± 30 seconds, but this will give position within ±0.015 foot at 100 feet. For plotting with a protractor, the nearest 15 minutes will usually be accurate enough.

295. Rectangular Coordinates. When the distance left and right of a line established by two stations is more important than the distance along the line, as often happens when the objects are near the line and the line is comparatively long, **the plus and offset** of each object is measured. The point on line opposite the object is estimated, the plus determined, and the offset distance measured from the line of sight to the object. The plus of all the objects can be determined by carrying a single measurement along the line. This eliminates a long measurement to each of the many objects from a distant station. Plotting is obviously materially facilitated by this method (see Figs. 6, 7).

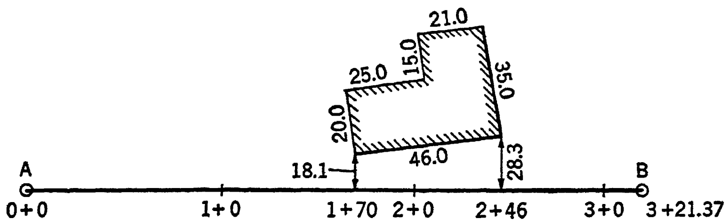


FIG. 6.—Plus and offset measurements.

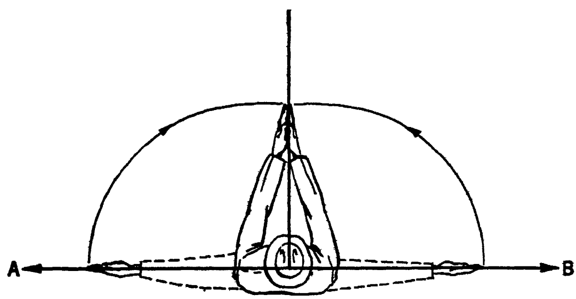


FIG. 7.—Estimating a perpendicular.

296. Other Methods of Obtaining Horizontal Ties. In order to reduce field work or to overcome obstacles, a number of other methods are often used instead of the two described. They consist in making the following measurements:

Focal coordinates. The directions to the object from two stations. (This is really triangulation.)

Linear coordinates. The distances to the object from two stations.

Resection from three points. The two angles formed **at the object** by lines to three stations.

Resection from two points. The distance to a station and the angle formed **at the object** by lines to that station and one other.

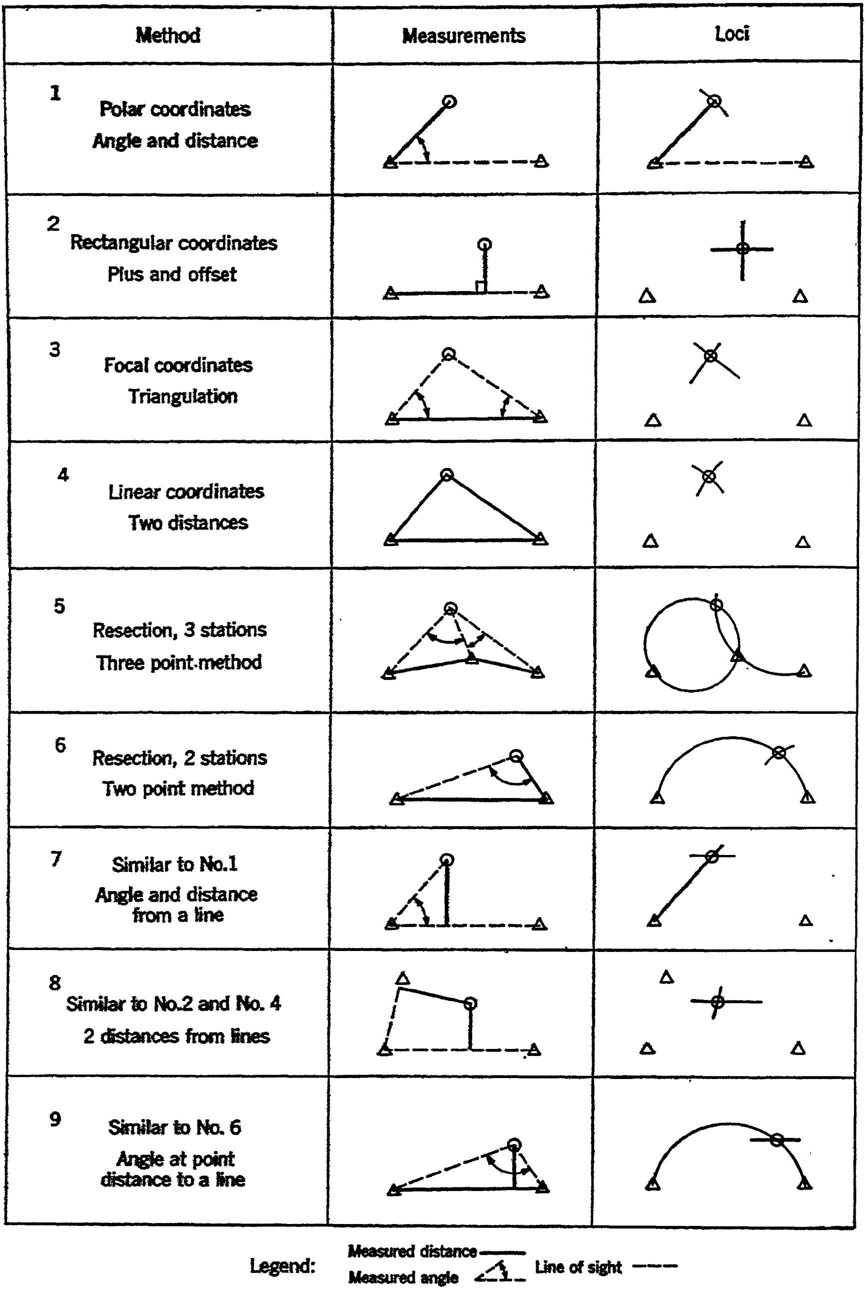


FIG. 8.—Methods of making horizontal ties.

297. Measurement from Lines. The distances mentioned in the preceding paragraphs can be measured to lines instead of points.

298. Strong Figures. The methods described above are collected in Fig. 8. In general, a point can be tied to control by making two measurements (angular or linear) provided that each measurement determines a locus for the point.

299. When these loci intersect at right angles, an error in measurement will result in an equal error in position. When the angle of intersection of the loci is less than 90 deg an error in measurement will

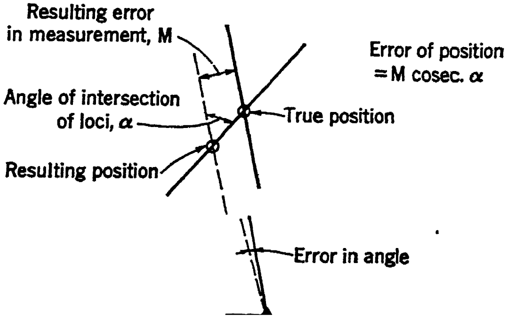


FIG. 9.—Error in position.

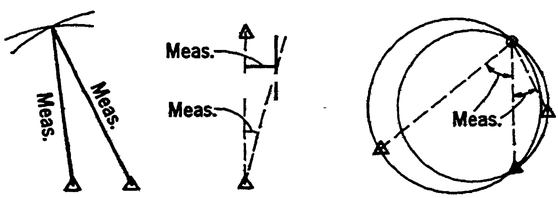


FIG. 10.—Some examples of weak ties showing loci.

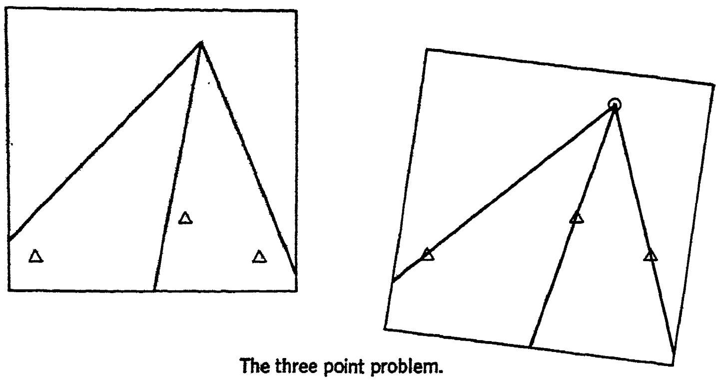
introduce an error in position equal to its value multiplied by the cosecant of the angle of intersection of the loci (see Fig. 9).

300. Thus, the more nearly the loci intersect at right angles, the more accurately the position is obtained. When the measurements are arranged so that the accuracy is high the tie is said to form a **strong figure.** Often the choice of methods depends on the strength of figure involved.

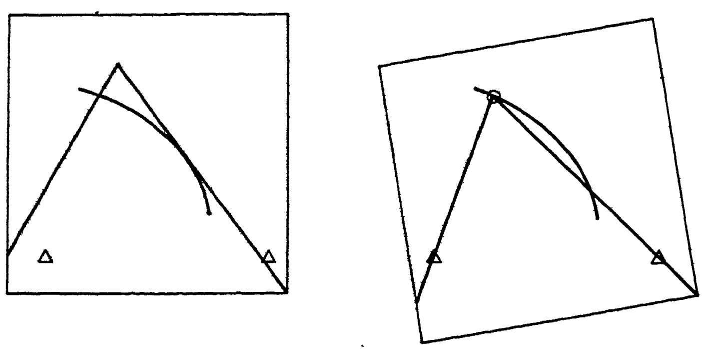
301. Plotting from Horizontal Ties. The position of an object is plotted by establishing the intersection of the two loci. Coordinates can be computed by trigonometry if desired.

302. A location by resection can be plotted by constructing the circle that forms the locus of the vertex of each angle, but this is rather involved.

It is better to construct the angles on tracing paper and fit them to the required stations (see Fig. 11). When many points are located by the three-point method, a **three-armed protractor** should be used (see Fig. 12).



The three point problem.
The correct angles are plotted on tracing paper or set on a three armed protractor and the position of the point found by trial



The correct angle is plotted on tracing paper and the vertex fitted to the arc representing the distance from one station while the sides pass through the stations

FIG. 11.—Plotting a point located by resection.

303. Measurement of Features. It is usually advantageous to measure the **dimensions** of buildings, roads, etc., as well as the ties to control. The dimensions are used to check or supplement the ties. For example, if the exact position of a building is required, all the corners are tied to the control and all the dimensions are measured as a check. If less accurate data will suffice, the dimensions are measured but only

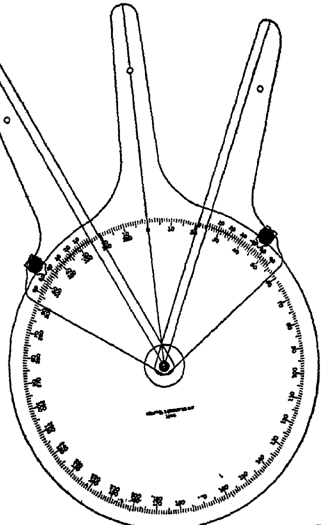


FIG. 12.—A three-armed protractor. (*Keuffel & Esser Co.*)

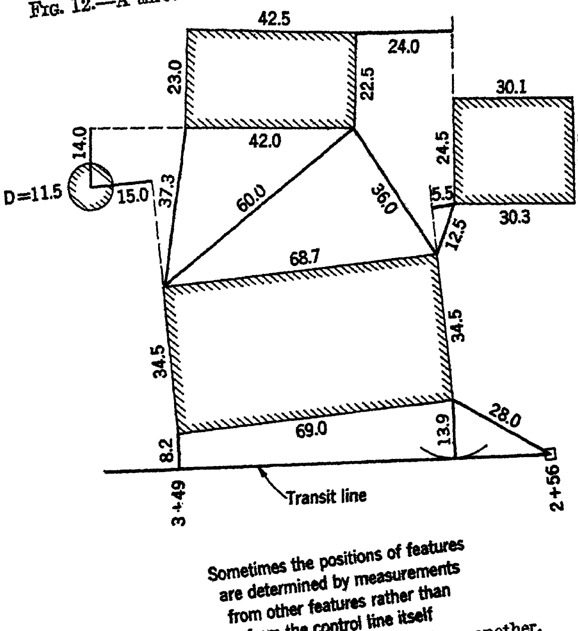


FIG. 13.—Locating one feature from another.

two corners are tied in. In this case the corner angles are assumed to be 90 deg. Ties to the center line of a road are sufficient under the same conditions. The width of the road is of course measured.

304. Locating One Feature from Another. Often time can be saved by tying features to each other instead of directly to control (see Fig. 13).

TRAVERSE AND ALIGNMENT OPERATIONS

305. Preliminary Survey Operations. The four operations described in the following paragraphs are chiefly useful in the determination of position, i.e., in the preliminary survey.

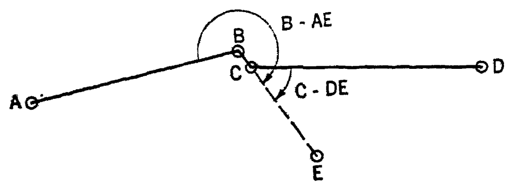


FIG. 14.

306. Angles on a Short Course (see Fig. 14). With a short course as *BC* in a traverse, the direction of *CD* with respect to *AB* cannot be determined by measuring the angles in the usual way, for a slight error in setup or the positioning of the target at *B* or *C* would introduce a large angular error.

Set up at *B*. Pick or set a well-defined point as far away as convenient at *E* on line with point *C*. Measure the angles *B-AE* and *C-DE*. Compute $C\text{-}BD = 180° - (C\text{-}DE)$.

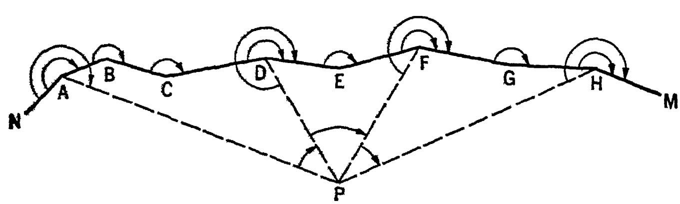


FIG. 15.

307. Carrying Direction on a Long Traverse. In hilly country the direction should be taken to a high point *P* and back to the traverse when possible (see Fig. 15).

Measure the angles shown. Adjust, giving greater weight to directions compiled through *P*.

In nearly level country the direction should be carried on sight lines that extend between the highest of the traverse stations (see Fig. 16).

Measure the angles shown. Adjust the angles, giving greater weight to the directions compiled through the **azimuth line ADFI.**

308. Steadying the Tape. When plumb bobs are used, the tape should be held as near the ground as feasible to reduce the plumb-bob swing. When possible, only one bob should be used. The tape should then be steadied at the other end by pressing it lightly against the stake or mark (see Fig. 17).

FIG. 16.

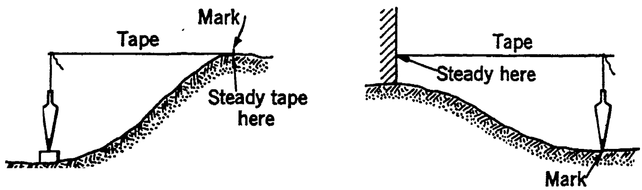


FIG. 17.

309. Swing Offset (see Fig. 18). It is required to measure a perpendicular from a point P to a line AB. Set up at A, and point on B. Swing a tape or a leveling rod as shown, finding the shortest distance. When the tape is near the transit, the graduations are turned toward the transit and the least reading is noted by the transitman. Otherwise, a yellow pencil or target is held on the tape or rod and adjusted until it

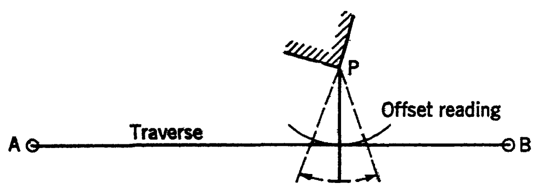


FIG. 18.

just touches the line of sight when the tape is swung back and forth. The final position of the pencil or target is used.

To **establish line** at a certain perpendicular distance from P, the tape or rod is swung as before. The transitman points at the greatest distance reached by the proper mark on the tape or the rod.

310. Location Survey Operations. The five operations described in the following paragraphs are chiefly useful in establishing line, i.e., in the location survey.

311. Double Centering (see Fig. 19). When a line such as AB is to be prolonged from B to C, the transit may be set up at A, and pointed at B, and C may be set on line.

This method is unsatisfactory, for a long prolongation, for the point C may be too far away to be set accurately, or rolling ground may interfere.

The usual method, therefore, is to set up the transit at B, point at A with the telescope reversed, then transit the telescope to its direct position and set C. If the transit is in adjustment, this method will give

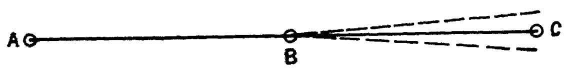


FIG. 19.

correct results. If the transit is out of adjustment, particularly if the line of sight is not perpendicular to the horizontal axis, this method will not produce a straight line.

If the transit is not known to be in adjustment, the operation described must be repeated with the telescope in the opposite positions to those used before. A is pointed with the telescope **direct** and C set with it **reversed.** This will result in a second mark for C if the transit is out of adjustment. The final point C is then set halfway between the two marks.

The process is known as **double centering.** It is difficult in the field when the men are out of earshot. Each man must have a clear idea of exactly what is being accomplished during each operation.

312. To Wiggle In, between Two Points. Frequently it is necessary to establish a point on line between two marks when it is impossible

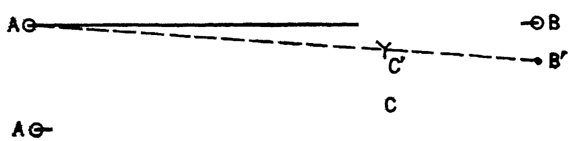


FIG. 20.

to set up over either of them. This occurs often in shop alignment and in the field when a point must be set on a hill that intervenes between the two marks.

In Fig. 20 assume that it is required to set a point C between the marks A and B. Set up at C' approximately on line. Choosing the most distant mark, point on A reversed, transit, and set B'. Measure B' to B. Estimate the ratio AC/AB, and move the transit from C' to C, computing this distance as follows:

$$\frac{C'C}{B'B} = \frac{AC}{AB}$$

Repeat the procedure until B' falls on B. When $B'B$ becomes small, the position B' must be established each time by double centering. When the direct and reversed shots are equally spaced each side of B, the transit is on line and C can be set under the plumb bob.

313. To Set a Point near a Transit. The telescope cannot be lowered far enough or focused close enough to set a point on line nearer

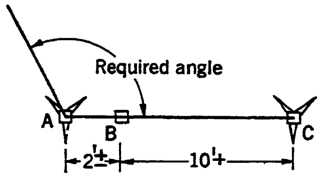


FIG. 21.

the transit than at about 4 feet. At less than 4 feet the following is necessary (see Fig. 21).

Set up at A, it being required to set B. Set a point C on the proper line. Set up on C. Point A, and set B on line.

314. To Set a Point of Intersection (P.I.). Frequently it is necessary to establish a point at the intersection of two lines, for example, the lines AB and CD (see Fig. 22).

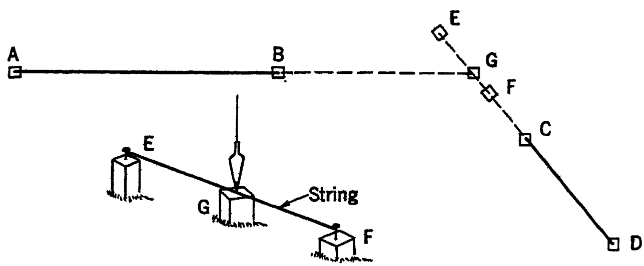


FIG. 22.

Set up at C. Set E by double centering, and point on the final position of E. Set F on line. E and F should be as near together as possible and yet lie one on each side of the prolongation of AB.

Tie a string from E to F.

Set up at B, and set a stake G on the line AB prolonged and also under the string. The stake should be driven down until the top just touches the string. Draw a pencil line on the top of the stake just under the string. Find the exact point of intersection on the pencil line by double centering from B.

315. Witnessing a Mark. Frequently it is necessary to make arrangements so that a mark can be easily replaced if disturbed. Two methods are indicated in Fig. 23. The supplementary marks are called **witnesses or witness marks,** and any ties are called **witness measurements.**

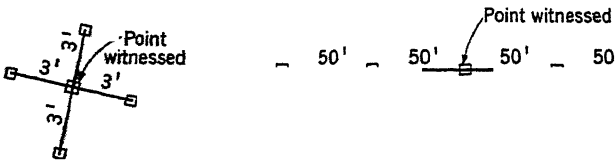


FIG. 23.

It is well to use a method that will serve even if only two witness marks remain.

OBSTACLES TO LINE AND LEVELS

316. Obstacles to Measurement but Not to Line. Water or other obstacles to measurement but not to sight are crossed by triangulation. The measured base should be about as long as the computed distance (see Fig. 24). All the angles should be measured, checked and adjusted so that their sum is 180 deg.

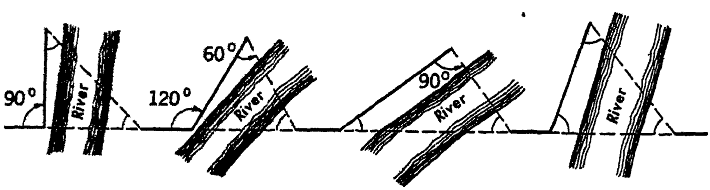


FIG. 24.

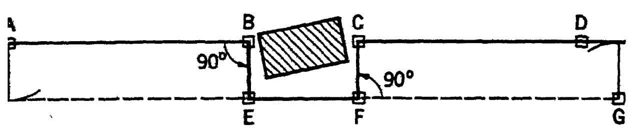


FIG. 25.

317. Right-angle Offset. In staking out a line, it is often necessary to carry distance and direction accurately beyond a small obstacle, as from AB to CD in Fig. 25.

At B turn 90 deg, and set E at a convenient number of feet. At E point a swing offset from A, and set G by double centering. Point G, and set F at a convenient number of feet. At F turn 90 deg, and set C so that $FC = BE$. At C point on a swing offset from G. Set D. While this method is simple and accurate, it takes about 2 hours and should be avoided if a quicker method is available.

318. Parallel Offset to Obstructed Line. A property or construction line is often marked at both ends but the entire length is obstructed. A parallel offset line is usually established and used instead (see Fig. 26).

Set C by estimating a position opposite A. Point a swing offset equal to AC at B, turn 90 deg, and measure a swing offset at A (usually a very small distance).

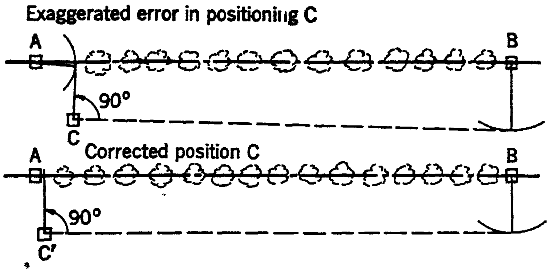


FIG. 26.

If the swing offset from A is large, move C back to C' and repeat the process. If it is small, add the value to measurements along the offset line from C.

319. Random Line. When a parallel offset line is impossible, a random line can be used to establish line points between the ends of an obstructed line (see Fig. 27).

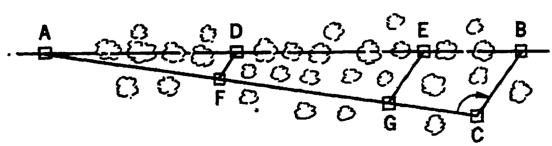


FIG. 27.

Set C at random but visible from A. Measure angle at C-AB. Compute any other desired positions as D, E, using the same angle, i.e.,

$$F\text{-}AD = G\text{-}AE = C\text{-}AB$$

320. High Obstacle on Line. Frequently an obstacle can be avoided by setting a point on high ground from which a line may be established over it or by setting a station on it. Distance can be carried over the obstacle by long plumb bobs, slope measurements, or triangulation (see Fig. 28).

321. Random Traverse. Of course any obstructed line can be replaced by a traverse. The length and direction of the obstructed line

can then be computed by trigonometry, traverse-computation technique being used if desirable. Sometimes time can be saved by orienting the coordinate system so that it coincides with one of the lines of the random traverse (see Fig. 29).

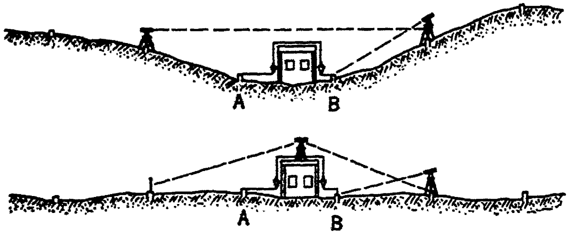


FIG. 28.

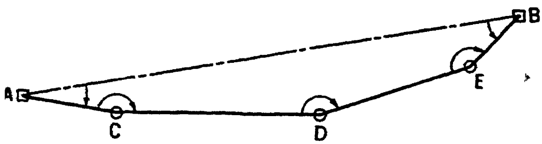


FIG. 29.—Random traverse. Choose a coordinate system so that *CD* is due east.

322. Measuring Vertical Clearance. To determine vertical clearance or the elevation of a point above the H.I., the rod can be used upside down. The rod reading must be given the opposite sign to that ordinarily used. It is often called a **minus rod** (see Fig. 30).

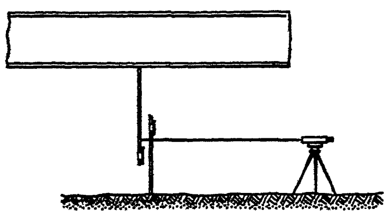


FIG. 30.

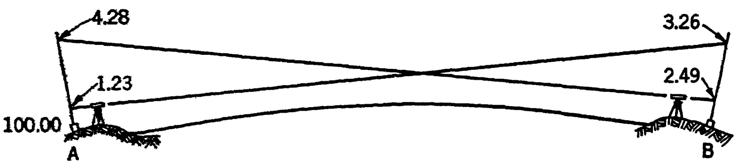


FIG. 31.

323. Reciprocal Leveling. When it is necessary to carry levels over a body of water, the plus sight and minus sight necessarily have different horizontal lengths. This introduces the instrument errors and,

in long sights, the effect of earth curvature. To eliminate these errors, the levels should be carried from the mark on one side to the other by two instrument setups, one on each side of the body of water. This will result in two elevations for *B*. The average is used (see Fig. 31).

Sta.	+	H.I.		rod elev.
B.M. *A*	1.23	101.23		100.00
B.M. *B*			3.26	97.97
B.M. *A*	4.28	104.28		100.00
B.M. *B*			2.49	101.79

97.97
101.79
2/199.76
Aver. 99.88 adopted elev. of *B*

324. Trigonometric Leveling. Often it is necessary to determine the elevation of an inaccessible point (see Fig. 32). Trigonometric

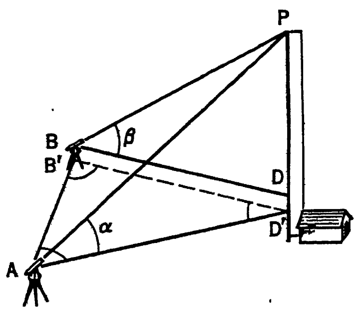


Fig. 32.

leveling is used. An allowance for the refraction of the air and earth curvature is necessary when the distances are great.

The length of the base *AB* and the angles shown are measured. The elevations of *A* and *B* are determined; then,

$$D' = 180° - (A + B')$$

$$AD' = \frac{AB'}{\sin D'} \sin B' \qquad D'P = AD' \tan \alpha$$

$$B'D' = \frac{AB'}{\sin D'} \sin A \qquad DP = B'D' \tan \beta$$

$$\text{Elev. } P = \text{elev. } A + D'P = \text{elev. } B + DP$$

PROBLEMS

The following are the measured values of the angles of the triangulation in Fig. 2: Base *AB* 628.32 ft. Base *GH* 485.52 ft.

Angle		Angle	
C-AB	60°10′25″		
A-BC	59 22 15	*B-CA*	60°27′35″
D-CB	62 31 53		
B-DC	61 29 43	*C-BD*	55 58 33
E-CD	64 08 25		
C-DE	55 28 15	*D-EC*	60 23 05
F-ED	55 42 00		
D-FE	65 06 50	*E-DF*	59 11 10
G-EF	66 30 18		
E-FG	63 51 28	*F-GE*	49 38 08
H-GF	65 44 45		
F-HG	46 46 55	*G-FH*	67 28 35

1. Adjust the angles.
2. Assuming the bearing of *BD* is due east (N 90° E), compute the bearings.
3. Compute the lengths of the sides.
4. Assuming that the coordinates of Station *A* are N 100.00, E 100.00, compute the coordinates of other stations.
5. In Fig. 4 describe how the transit would be oriented at Station *B*.
6. The following are the values of the angles obtained in Fig. 15. Adjust the angles and compute the azimuths without changing (holding fixed) the angles on the azimuth control line. Azimuth *NA* 42°25′30.″

A-NP	248°32′20″	*A-NB*	206°10′10″
B-AC	219 42 20		
C-BD	154 14 50		
D-PE	308 18 40	*D-CE*	195 23 40
E-DF	157 47 30		
F-PG	252 05 10	*F-EG*	207 10 30
G-FH	171 22 40		
H-PM	224 04 10	*H-GM*	196 10 20
P-AD	38 41 20		
P-DF	61 11 10		
P-FH	35 33 00		

7. Compute the elevation of turning point B in Fig. 31 if the rod readings were the following:

Instrument at	Rod at	Reading
A	A	2.45
A	B	7.28
B	A	6.39
B	B	11.16

8. In Fig. 32 compute the elevation of the top of the chimney from the following data:

$AB' = 261.28$ Elev. $A = 82.36$
$A = 62°37'$ Elev. $B = 85.10$
$B' = 56°14'$
$\alpha = 25°41'$
$\beta = 23°45'$

9. In Fig. 29 compute the length of AB from the following data:

A 21°36′	E 152°24′	$AC = 101.60$
C 167°53′	B 38°04′	$CD = 242.43$
D 160°08′		$DE = 169.94$
		$EB = 75.31$

CHAPTER XIII

TOPOGRAPHIC SURVEYING

325. The Topographic Map. A topographic map is the basis for almost all projects. It shows the horizontal positions to scale of contour lines, natural features, roads, and structures. Often it includes boundaries, coordinate lines, survey control marks, spot elevations, true and magnetic north, and other features. The survey for such a map consists of the establishment of vertical and horizontal control systems arranged for the particular work in hand and the measurement of ties that connect the various features to this control.

326. Topographic Surveys. In general, there are two types of topographic surveys, **area surveys** and **route surveys.** Area surveys have appreciable width as well as length. Route surveys provide strip maps for the location of railroads, highways, pipe lines, transmission lines, canals, etc. An area survey requires a control **network** of stations and bench marks, even though the network may be rudimentary when the area is small. Most of the horizontal ties in an area survey are made by angle and distance. A route survey is controlled by a single traverse and profile extending throughout its length, and the horizontal ties are made chiefly by plus and offset.

327. When either type of survey is large, aerial mapping is the most economical method. Lack of accuracy does not limit this process, for contours with as small an interval as 2 feet have been accurately mapped by one aerial mapping system. Aerial mapping usually requires less detailed control and comparatively few ties.

THE STADIA METHOD

328. The Use and Principle of the Stadia Method. The stadia method provides the most useful means of making angle and distance ties, and it is the most rapid means of determining differences in elevation. It is therefore practically indispensable for topographic mapping.

329. For stadia measurements the instrument is equipped with two supplementary horizontal cross hairs equally spaced above and below the center hair (Fig. 1). The apparent intercept between the stadia hairs on a level rod or the like can be used to determine the slope distance from the instrument to the rod to an accuracy of about 1 part in 300.

When the vertical angle is also measured, the horizontal distance and the difference in elevation can be computed. These data, together with the direction of the rod obtained from the reading of the horizontal circle, complete a three-dimensional tie for the rod position.

330. The Stadia Theory. The computation of vertical and horizontal distances from stadia intercepts is accomplished by two sets of formulas. One set applies to the instruments that are focused by moving the objective lens, and the other set applies to internal-focusing instru-

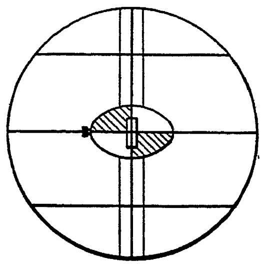


FIG. 1.—Stadia hairs and rod.

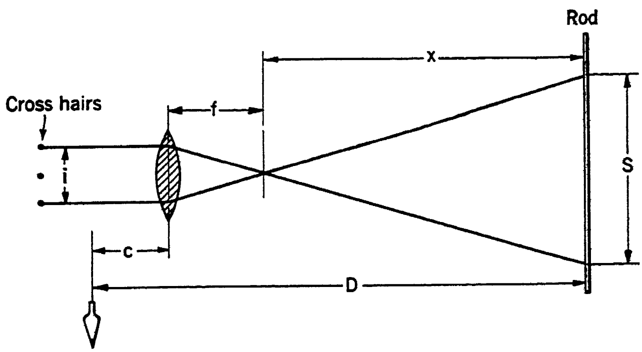


FIG. 2.—External-focusing instrument used for stadia measurements.

ments. The values of the constants in the formulas depend on the design and construction of each individual instrument.

331. Stadia Formulas for External-focusing Instruments. Figure 2 shows the conditions that exist when the line of sight is horizontal.

From the figure:

$$= \frac{f}{i} \qquad \text{or} \qquad x = \frac{f}{\ }$$

$$D = \frac{f}{i} s + f + c$$

D is the distance from the plumb bob to the rod and is therefore the distance desired.

332. Inclined Stadia Shots. Figure 3 shows the conditions that exist when the line of sight is inclined. The height of the center of the instrument above the stake or other mark is known as the **h.i.** It is measured by holding the rod beside the instrument at the level of the

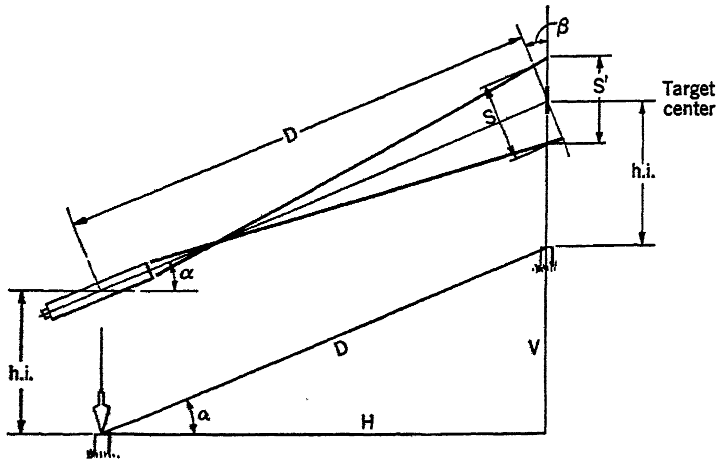


FIG. 3.—Inclined stadia observation.

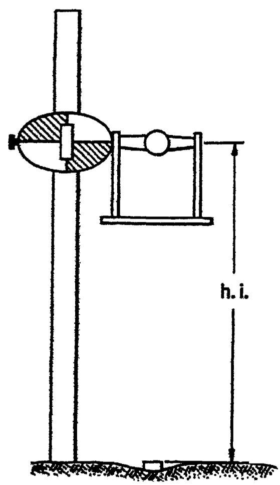


FIG. 4.—Determining the h.i.

stake (see Fig. 4). The target is set at this value. When the rod is placed on the point to be located, the center cross hair is pointed at the target as shown (see also Fig. 1). The line of sight is thus made parallel with the line from the top of the stake to the point to be located.

$$s = s' \cos \beta \quad \text{(very nearly)}$$
$$\beta = \alpha \qquad \text{sides perpendicular in the same order}$$

But

$$D = \frac{f}{i} s + f + c$$

By substitution,

$$D = \frac{f}{i} s' \cos \alpha + f + c$$

But

$$H = D \cos \alpha$$
$$V = D \sin \alpha$$

Hence,

$$H = \frac{f}{i} s' \cos^2 \alpha + (f + c) \cos \alpha$$

$$V = \frac{f}{i} s' \sin \alpha \cos \alpha + (f + c) \sin \alpha$$

The cross hairs are usually spaced so that $f/i = 100$. In this case the formulas may be written

$$H = s'100 \cos^2 \alpha + (f + c) \cos \alpha$$
$$V = s'100 \sin \alpha \cos \alpha + (f + c) \sin \alpha$$

333. Determination of the Stadia Constants of an External-focusing Instrument. While in most instruments the value f/i is 100 and $f + c$ is approximately 1 foot, these values must sometimes be

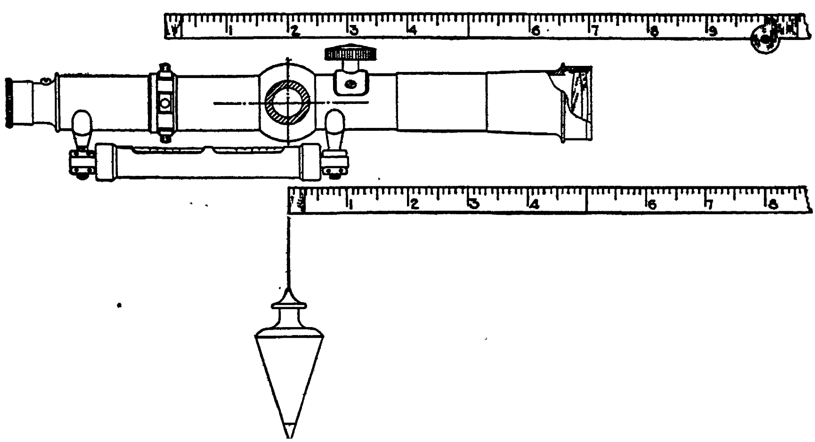


FIG. 5.—Measuring stadia constants. $f = 6.8$ inches, $c = 4.8$ inches. Therefore $f + c = 11.6$ inches which can be called 1 foot. (*C. L. Berger & Sons, Inc.*)

checked. f/i must be known exactly, and $f + c$ should be known within about 0.1 foot. They can be determined by the following procedure:

1. Focus on a distant point (800 feet or more away), and measure from the estimated center of the lens to the cross-hair adjusting screws (see Fig. 5). This gives the value of f. It is to be remembered that the focal length is the same both in front of and behind the lens. When the telescope is focused at a distant point, the principal focus is brought on the plane of the cross hairs and the focal length can be measured as described.

2. Focus on a point about 100 feet distant, and measure from the lens to the instrument center. This will give the value of c. Although

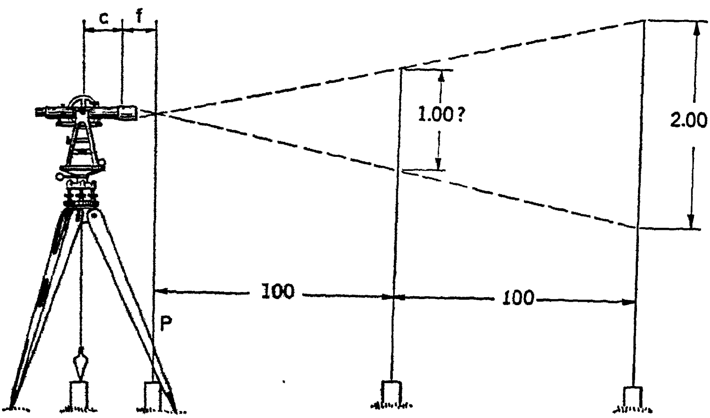


FIG. 6.—Determining $\frac{f}{i}$ (the stadia constant) for an external-focusing instrument.

c changes with different distances as the lens is moved in and out, an average value is sufficiently accurate.

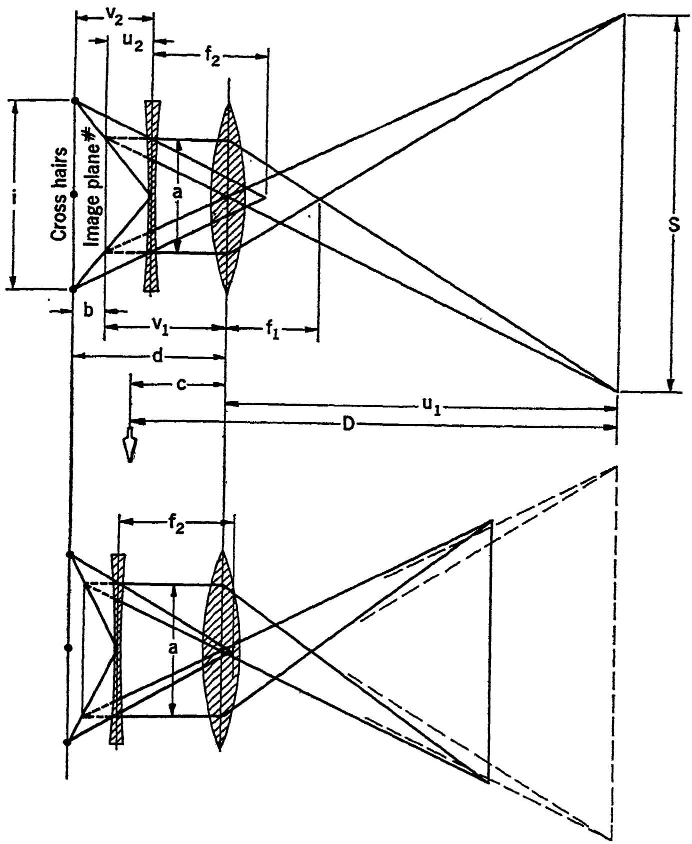
3. Measuring from a point P, shown in Fig. 6, which is a distance of $f + c$ from the plumb bob, place marks at 100 feet and 200 feet (see Fig. 6). Keeping the telescope level, read the stadia intercepts at these points. Then

$$\frac{f}{i} = \frac{x}{s}$$

where x is the distance from P.

334. The Stadia Formulas for Internal-focusing Instruments. Figure 7 shows the conditions that exist in an internal-focusing instrument. The upper diagram illustrates a comparatively long sight, and the lower figure illustrates a shorter one. The dotted lines show part of the upper diagram superimposed on the lower figure.

The objective lens and the cross hairs are fixed in the telescope. The image is brought on the plane of the cross hairs by moving the



#A real image would be formed here except for the negative lens. This image can be considered the object of the negative lens

FIG. 7.—Internal-focusing instrument used for stadia measurements.

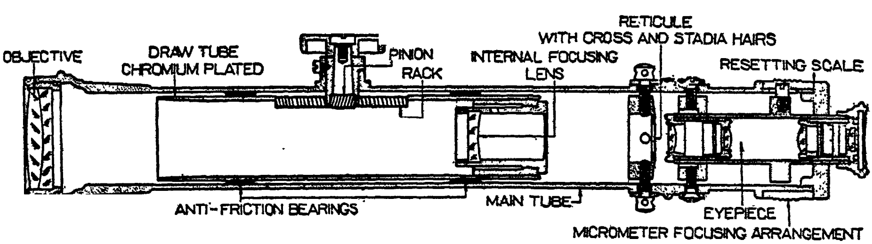


FIG. 8.—Cross section of an internal-focusing telescope. (*Keuffel & Esser Co.*)

negative lens. As it is moved toward the rear of the telescope to focus on a nearer object, the distance a (which is controlled by the separation of the stadia hairs) increases so that the ratio between the distance of the object and the stadia intercept is changed. This is illustrated by the change in slope from the dotted lines to the full lines. Instruments can be designed, however, so that this change is negligible and, in fact,

$$D = 100s \qquad \text{(very nearly)}$$

For example, when an instrument has the constants given below, if the cross hairs are set so that they intercept exactly 1.00 when D is 100 feet, then the following occurs (values are given in feet):

When
$$f_1 = 166 \text{ mm}$$
$$f_2 = 142 \text{ mm}$$
$$d = 208.4 \text{ mm}$$
$$c = 140 \text{ mm}$$

D	10	100	500
s	0.0966	1.0000	5.0175
Error in D	0.34	0	1.75

Since the errors of plotting at the largest usual scales are greater than 0.34 foot and the error of reading the rod at 500 feet is nearly 0.02 foot, the errors shown above are negligible.

The formulas required for this computation can be derived as follows:
From Fig. 7,

$$u_1 = D - c \tag{1}$$

and

$$\frac{s}{a} = \frac{u_1 - f_1}{f_1} = \frac{u_1}{v_1} \qquad \frac{a}{i} = \frac{f_2}{v_2 + f_2} = \frac{u_2}{v_2}$$

Hence,

$$v_1 = \frac{u_1 f_1}{u_1 - f_1} \tag{2}$$

$$u_2 = \frac{v_2 f_2}{v_2 + f_2} \tag{3}$$

and

$$\frac{s}{i} = \frac{u_1}{v_1} \times \frac{u_2}{v_2} \tag{4}$$

From the figure,

$$b = d - v_1 = v_2 - u_2 \tag{5}$$

Substituting (3) in (5),

$$b = v_2 - \frac{v_2 f_2}{v_2 + f_2}$$

Solving for v_2,

$$v_2 = \frac{b \pm \sqrt{b^2 + 4bf_2}}{2} \tag{6}$$

When the values of f_1, f_2, d, and c are known, the value s/i can be found for any value of D as follows:

Solve (1) for u_1, (2) for v_1, (5) for b, (6) for v_2, (5) for u_2, and (4) for s/i.

When the relation s/i is known, the separation between the wires can be computed for any desired intercept, and vice versa.

335. Inclined Stadia Shots with Internal-focusing Instruments. Since D can be taken as equal to $100s$, the formulas for inclined shots are

$$H = 100s' \cos^2 \alpha$$
$$V = 100s' \sin \alpha \cos \alpha$$

336. Determination of the Constants for an Internal-focusing Instrument. By reading the stadia intercepts at various values of D the exact values of D/s can be determined. Obviously, if the value is near enough 100 for the work involved, 100 should be used. If precise results are necessary, a correction chart should be constructed.

337. Stadia Reduction Devices. Special tables, charts, and slide rules have been devised that facilitate stadia computations. An excellent circular slide rule is shown in Fig. 9. Stadia tables are given in Part II of this text.

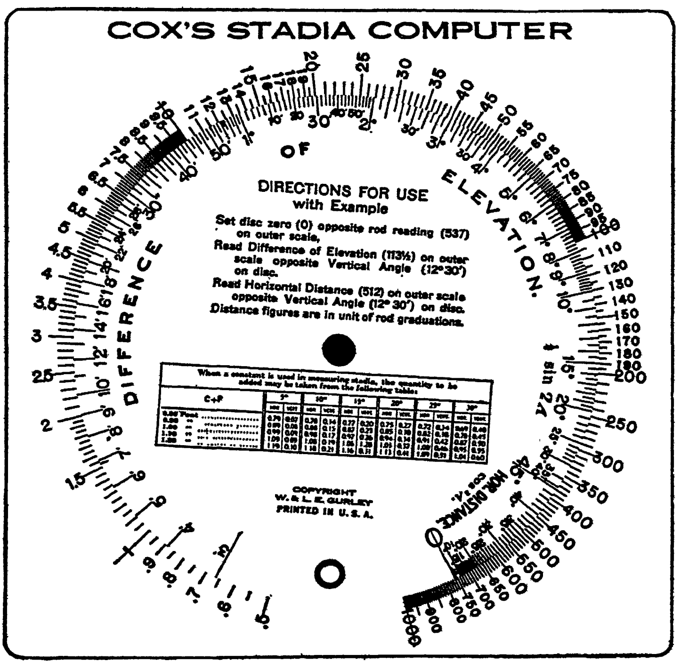


FIG. 9.—A stadia circular slide rule manufactured by W. & L. E. Gurley. (*W. & L. E. Gurley.*)

The devices are based on the assumption that $f/i = 100$. They give the following values in one form or another.

$$\text{For } H,\ 100 \cos^2 \alpha \quad \text{and} \quad (f + c) \cos \alpha$$
$$\text{For } V,\ 100 \sin \alpha \cos \alpha \quad \text{and} \quad (f + c) \sin \alpha$$

338. For a precise solution, the two terms of the equations are solved separately. The first term is found by entering the table with α and multiplying the tabulated value by the stadia intercept. The stadia slide rule performs this multiplication when the stadia intercept and α are set on the scales. The second term is found by entering the table computed for an $f + c$ nearest to that of the instrument, the argument α being used. The sum of the results for the two terms gives the value required.

339. A quicker procedure is ordinarily used. Although approximate, it usually introduces much less error than the reading of the stadia intercept. Since the vertical angle is usually small (10 deg or less) and $f + c$ is usually a small fraction of the distance, the second terms of the formulas can be multiplied by the cosine of α without materially changing the results. Thus,

$$H = s'100 \cos^2 \alpha + (f + c) \cos^2 \alpha$$

or

$$H = \left(s' + \frac{f + c}{100}\right) 100 \cos^2 \alpha$$

Similarly,

$$V = \left(s' + \frac{f + c}{100}\right) 100 \sin \alpha \cos \alpha$$

The procedure therefore consists in mentally adding $(f + c)/100$ to the stadia intercept and solving only the first terms of the formulas.

Example. Assume $f + c = 1.00$, $s' = 3.00$, $\alpha = +10°00'$. By the true formulas,

$$H = (3.00)100 \cos^2 10° + (1.00) \cos 10° = 291.940$$
$$V = (3.00)100 \sin 10° \cos 10° + (1.00) \sin 10° = +51.476$$

By the approximate formulas,

$$H = (3.01)100 \cos^2 10° = 291.925$$
$$V = (3.01)100 \sin 10° \cos 10° = +51.474$$

Since the error in reading the instrument is at least 1 part in 500, the errors shown above are negligible.

340. Use of Stadia Computing Devices for Internal-focusing Instruments. As shown previously, $f + c$ can be considered equal to

zero for internal-focusing instruments. For these instruments only the first terms of the formulas are used.

341. Stadia Observations. When the stadia is used for making ties, the instrument is set up at a horizontal control station. The h.i. is measured and recorded, and the target is set at this value. The instrument is oriented as described in Art. 293 by pointing at a second control station, usually with the vernier set at the azimuth of that direction.

To make the tie, the rodman holds the rod at the point to be tied in. The center of the cross hairs is pointed on the target, by means of the upper motion and the vertical motion. With the vertical-motion tangent screw, the line of sight is then raised or lowered until the lower stadia hair falls on the nearest foot mark. The stadia intercept is read by mentally subtracting the position of the lower hair from the position of the upper hair. It is recorded, the center hair is moved back to the target, and the "all right" signal is given to the rodman. While the rodman is moving to the next point, the horizontal angle and the vertical angle are read and recorded.

At some time during the work at each station, an observation must be made on a point of known elevation. Just before picking up the instrument the orientation should be checked by again pointing on the station used for orienting.

342. Special Stadia Observations. When the rod is too far distant to observe the full stadia interval, a half interval is sometimes used. The accuracy is cut in half.

343. When the target previously set at the h.i. on the rod is not visible, any other mark on the rod can be sighted instead, but its value must be recorded (see Fig. 10). The elevation for a point where such a procedure is used is obtained by computing an elevation in the usual way and correcting it by the difference between the mark sighted on the rod and the h.i., thus:

$$\text{True elev.} = \text{computed elev.} - (\text{mark sighted} - \text{h.i.})$$

344. Often the magnetic bearings of some of the observations are read as approximate checks on the azimuths.

345. Level Stadia Shots. The necessity for stadia reductions can be eliminated by taking **level stadia shots.** It is then necessary only to add the value of $f + c$ to the stadia distances.

The telescope is leveled for each observation, the attached level being used and the reading of the center hair is recorded. The lower hair can then be set at the nearest foot mark and the intercept determined. If all observations are made in this manner, ordinary level notes and

methods can be used for elevations, the h.i. is omitted, and of course no vertical angle is read.

In small surveys where differences in elevation are not great, level shots are great timesavers and should always be used.

346. Stadia Traverse. A complete traverse can be run by stadia. Since the distance accuracy is low, angles to the nearest minute are more than accurate enough. To simplify plotting it is therefore standard practice to carry the azimuth throughout. The instrument is oriented at each succeeding station by observing the previous station with the back

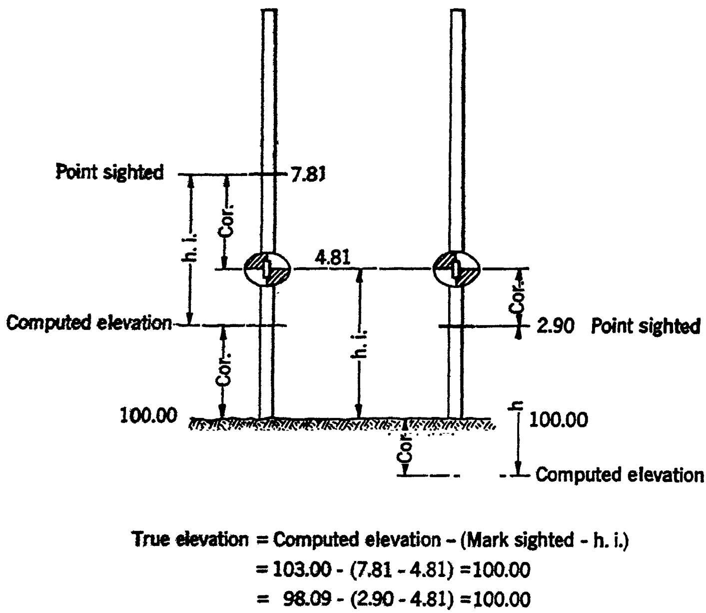


FIG. 10.—Corrections when point sighted on rod is not *h.i.*

azimuth set on the vernier. Traverse procedure is given in detail in the following paragraphs (see Fig. 11).

347. Stadia Connecting Traverses. The first stadia station in a stadia connecting traverse is a previously established control station. The instrument is oriented at that station in the usual way. Immediately after the orientation observation, a stadia shot is taken to the second stadia station, which is on the stadia traverse. This shot gives the azimuth of that station, the length of the course, and the difference in elevation. An observation is then taken on a point of known elevation. All necessary topographic shots are taken next. Finally, the orientation of the instrument is checked by again observing the station that was used for initial orientation.

At the second stadia station the back azimuth of the first course is computed by adding ± 180 to the forward azimuth. The vernier is set at this value, and the instrument is pointed at the first station with the lower motion.

Immediately after orientation, a regular stadia shot is completed on the first station, i.e., the stadia intercept, the azimuth, and the vertical angle are read. The stadia intercept should be the same as the forward stadia intercept within the limits of reading the rod. It is usually acceptable if within ±0.02 foot. The azimuth, of course, has been just set for orientation. The reading constitutes a check on the setting and on the fact that the lower motion was used to point the instrument. The vertical angle should have the opposite sign to the forward vertical angle and should numerically agree within ±2 minutes. Averages are used for computation.

The next stadia shot should be on the next stadia station. Following this are the topography ties and finally the orientation check.

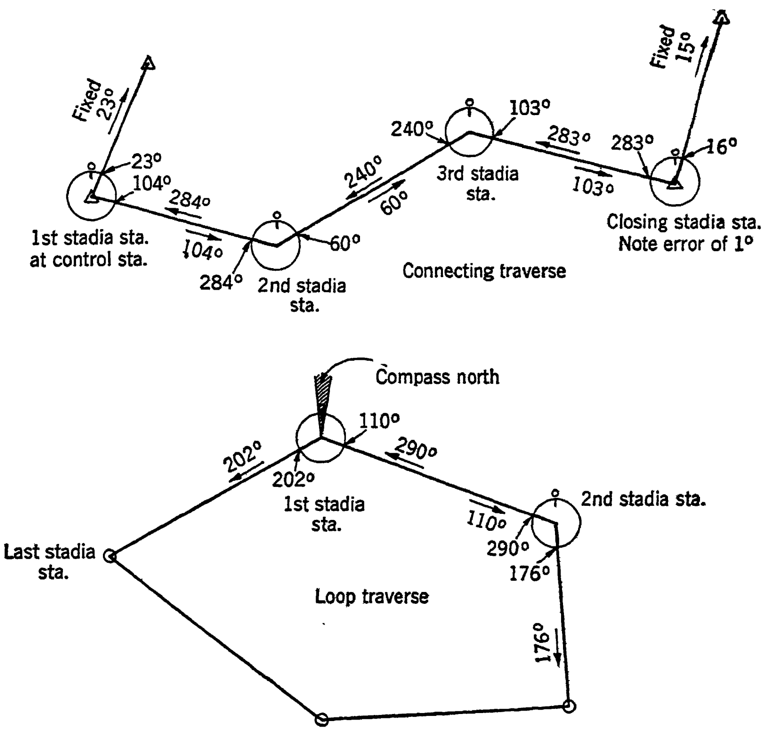


FIG. 11.—Diagrammatic plans of orientation of instrument to carry azimuth forward.

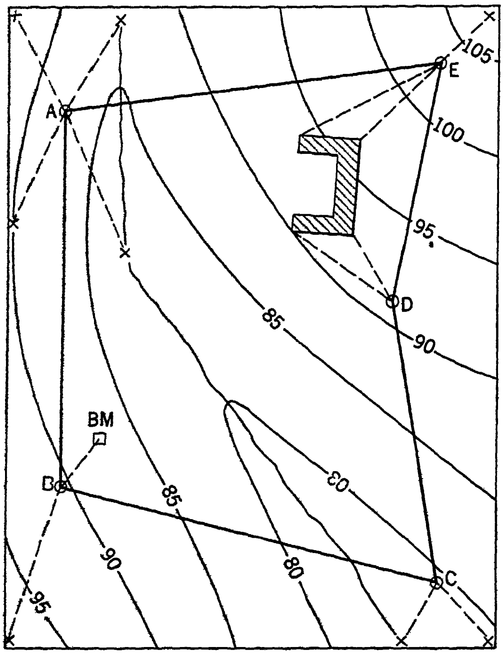
The traverse is closed by placing the last stadia station at a control station. There a second control station is observed, and also a point of known elevation. The azimuth of the second control station thus determined through the traverse is compared with the known azimuth. The difference is taken as the angular error of the traverse. The shot to the point of known elevation will result in a level closure when the computations are completed.

348. Stadia Loop Traverse (see Figs. 11, 12, 13). The first step in a stadia loop traverse is to mark at least three stations, the **first**, the **second**, and the **last**. The instrument is set up at the **first** station. The azimuth, of course, must be assumed. It is often convenient to assume the azimuth so that zero azimuth agrees with mag-

netic north as near as the compass will indicate it. This is seldom better than ±10 minutes.

The instrument is oriented at the first station by setting the vernier at zero and pointing the instrument with the lower motion so that the compass reads north. The **last** station is then observed using the upper motion. The azimuth of this station constitutes the real orientation, for it can be precisely regained, whereas the direction established with the compass cannot.

The stadia readings are completed on the last station, a stadia shot is taken on the second station, the ties are completed, and finally the orientation is checked on the last station.



Plant #2 site survey

FIG. 12.—Stadia loop traverse.

Thereafter the process is the same as for the connecting traverse.

When the last station is finally occupied, all closures are completed. A stadia shot, of course, is taken to the first station. To determine the angular error the forward azimuth thus determined is compared with the back azimuth originally established.

The elevation differences are closed so that a check is obtained independent of other elevations. A datum can be assumed or a standard datum can be used by observing at least one point of known elevation.

349. Stadia-traverse Closures. When a stadia traverse is closed, the angular error is immediately apparent in the field. If the error is in the neighborhood of or less than 1 minute times the square root of the number of stations, the azimuths are

accepted. No adjustment is made, for only blunders would be large enough to show in the plotting.

The position error is checked by plotting only.

The elevation error appears when the stadia elevation differences are computed. If this error is not greater than 0.8 foot $\sqrt{\text{miles}}$, it indicates no blunder and the

PLANT #2 SITE SURVEY

Ch Smith Date
π Jones Windy
Rod Kole

Sta	S	Azim	V∡	H	V	Elev.
π A	h.i	4.65				87.72
E	8.07	82°52'	+1°06'	—	—	
B	8.00	180°00'	+0°12'	801	~~+2.80~~ →	+2.83
	2.40	337°05'	+1°19'	241	+5.5	93.2
	2.28	31°30'	-0°15'	229	-1.0	86.7
	3.33	155°06'	-0°52'	334	-5.2	82.5
	2.65	204°28'	+0°30'	266	+2.3	90.0
π B	h.i	4 26				90.55
A	8.00	0°00'	-0°12'	—	—	
C	8.24	104°02'	-0°46'	825	~~-11.33~~ →	-11.30
BM	Level		7.75			87.06
	3.59	199°22'	+1°11'	360	+7.5	98.0
π C						79.25
B	8.26	284°02'	+0°48'	—	—	
D	6.10	350°32'	+1°04'	608	~~+11.54~~ →	+11.57
	1.70	137°35'	-0°04'	171	-0.2	79.0
	1.50	208°58'	-1°27'	151	-3.8	75.4
π D						90.82
C	6.10	170°32'	-1°06'	—	—	
E	5.11	11°18'	+1°22'	510	~~+12.38~~ →	+12.41
1	1.64	239°03'	+0°40'	165	+1.9	92.7
2	2.60	215°20'	-0°11'	261	-0.8	90.0
π E						103.23
D	5.13	191°18'	-1°24'	—	—	
A	8.09	262°52'	-1°06'	806	~~-15.53~~ →	-15.51
1	2.35	225°55'	-1°38'	236	-6.7	96.5
2	3.34	242°38'	-1°44'	335	-10.1	93.1
	1.42	44°10'	+1°57'	143	+4.8	108.0

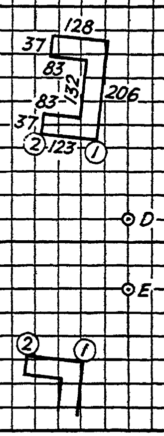


FIG. 13.—Field notes for the stadia survey shown in Fig. 12.

elevations of the traverse can be adjusted. They are usually adjusted in proportion to the lengths of the traverse courses.

350. Stadia Leveling. Stadia can be used for rapid profile and differential leveling. The procedure for profile leveling is the same as for traverse except that no horizontal angles are determined. Differential leveling can be carried out like profile leveling, or a special method may be used.

351. Special Method for Differential Leveling by Stadia. Two rods should be used, one for back observations and one for forward observations. The two rods and the instrument are all moved forward together. The targets are to be permanently set at any desired point on the rod. Usually 1 foot above the mid-point should be used. The value of the h.i. is disregarded, but the target positions should be **exactly the same** on both rods. To eliminate any error of target setting the front rod should be interchanged for the rear rod halfway between bench marks.

The procedure is shown in Fig. 14. It is much like differential leveling. The two differences in height between the instrument and the targets are applied with the proper signs to carry the elevations forward. The method is rapid but provides no check on the individual observations as does the usual procedure.

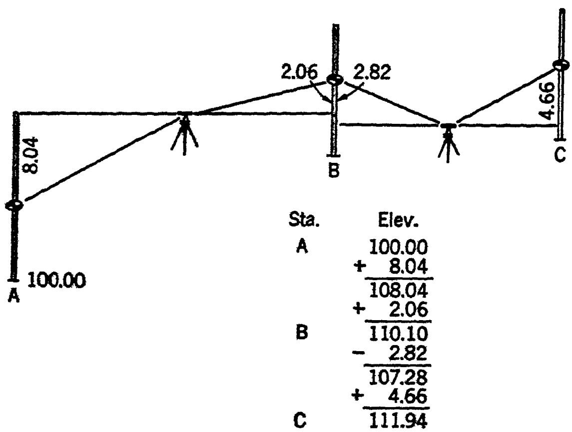


FIG. 14.—Differential leveling by stadia.

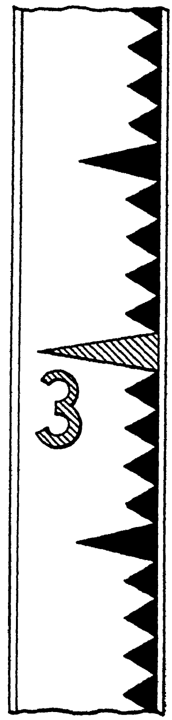


FIG. 15.—Part of a special stadia rod.

352. Special Stadia Equipment. Special rods are often used for stadia observations. They are designed for easy reading at long distances (see Figs. 15, 16). A handkerchief is usually tied around the rod for a target. Often instruments are equipped with specially graduated vertical scales, which give the stadia reduction coefficients for the vertical angle used. Reading the vertical angle can be omitted and these reduction values read instead. The distances and differences in height can be obtained by multiplying these values by $s' + \frac{f + c}{100}$. The device is known as the **Beaman arc** after the inventor (see Fig. 17). It eliminates use of the tables but requires one slide-rule computation and therefore is equivalent to a stadia slide rule in speed.

353. The Plane Table. A **plane table** consists of a drawing board on a tripod arranged for field use (see Fig. 18). The table can be leveled and turned and locked in azimuth. Used with the plane table is an alidade, which consists of a straightedge and sighting device. The sighting device is usually a telescopic sight with stadia

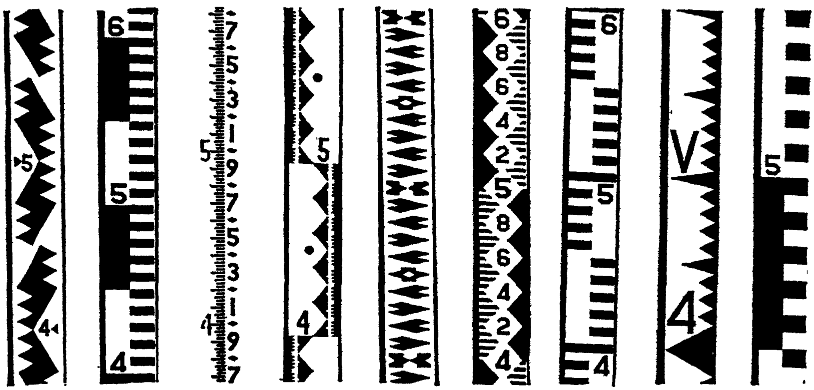


Fig. 16.—Various types of stadia rods. (*W. & L. E. Gurley.*)

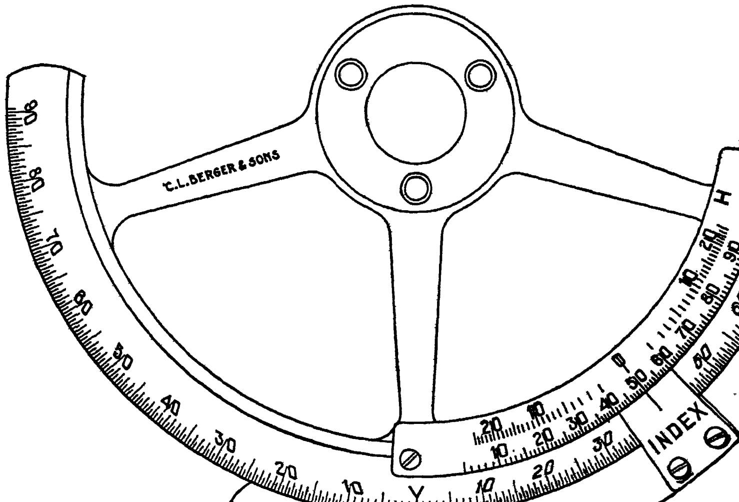


Fig. 17.—A Beaman stadia arc. (*C. L. Berger & Sons, Inc.*)

equipment. The alidade rests on the plane table and can be moved over it wherever desired.

Triangulation, traverse, and topography are placed on the map sheet on the board as the work progresses. The table can be oriented by placing the straightedge along a line on the map and turning the whole table until the line of sight points

along the corresponding line on the ground (see Fig. 19). Thereafter the directions to other points can be drawn by directing the alidade at the point desired while keeping the straightedge at the point on the map representing the station of the table on the ground.

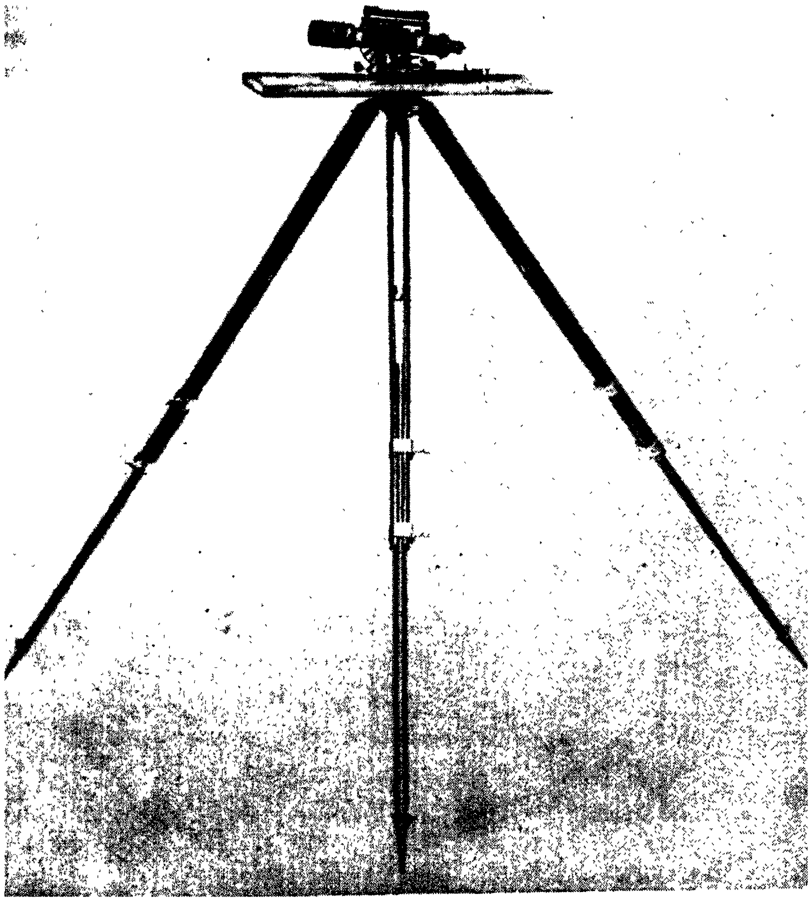


FIG. 18.—Plane table and alidade. (*W. & L. E. Gurley.*)

Distances and elevations are usually measured by stadia. The distances are immediately plotted and the elevations noted. Contours are sketched in while the actual ground is being viewed.

Next to aerial mapping equipment, the plane table is the most generally used instrument for mapping large areas. It is excellent for small surveys as well as large, and the method has been omitted from this text only because it is not essential to its purpose.

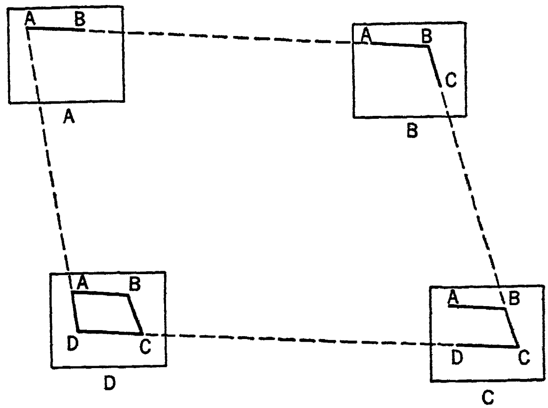


FIG. 19.—A plane table traverse.

TOPOGRAPHIC SURVEYS OF SMALL AREAS

354. Locating Contours. The methods of establishing control and making ties have been covered in this and other chapters. The problem remains of how to locate contours. In area surveys the positions and elevations of certain key points are determined, and the contour lines are interpolated between them. When greater accuracy is necessary, elevations are also determined at grid positions as described in Chap. X. The key points must be included even when the grid system is used.

355. Key Points for Contours. In general, key points are **those points between which the ground has a uniform slope.** Since the ground never slopes uniformly, the accuracy of the map depends on how small a change in slope is considered significant for the contour interval desired. The ability to select key points so that the desired map accuracy can be obtained with a minimum of field work is an art that develops with experience. However, if each of the following conformations is considered with a view to using it as a key point, there will be little chance for omissions:

1. Summits.
2. Saddles (low points in ridges).
3. Depressions.
4. Valley profiles.
5. Ridge profiles.
6. Boundary and building corners.
7. Profiles along buildings and boundaries.
8. Profiles along toes of slopes.
9. Profiles along brows of hills (tops of slopes).
10. Profiles along shoulders.

Figure 20 illustrates the typical key points found on a plant site. The numbers refer to the list above. Although many points fall into more than one classification, only one classification is shown.

356. Time can usually be saved by taking the elevations of points that must be located horizontally, like the corners of buildings and the

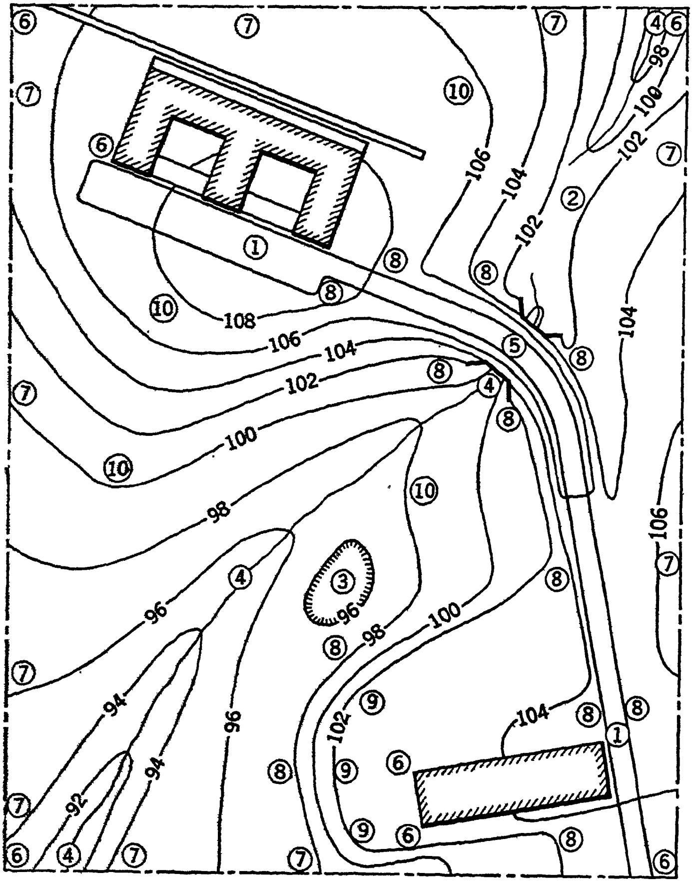
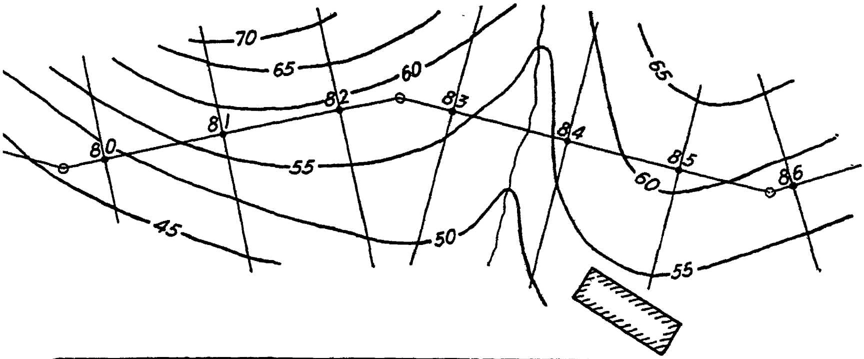


FIG. 20.—Key points for contours.

bends in streams. These points are usually key points, and, of course, no further measurements for horizontal position are required.

ROUTE SURVEYS

357. Use of Route Surveys. Even over short distances, route-surveying methods are advantageous for the strip maps necessary for roads, railway sidings, drainage ditches, and the like.



SURVEY FOR DRIVE

Sta.	ID	IDR	∡Used	Mg. Br.	Cal. Br. Dist.
86					
⊙85+79.6	150°02'	300°05'	150°02'		
85					
				S 76-00 E	S 76-10 E
84					329.3
+65					
83					
⊙82+50.3	205°32'	51°04'	205°32'		
82					
				N 78-20 E	N 78-18 E
81					284.1
80					
⊙79+66.2	150°13'	300°27'	150°13'		

Ch. Smith
π Jones
H.C. Kole
R.C. Ely

Date
Clear

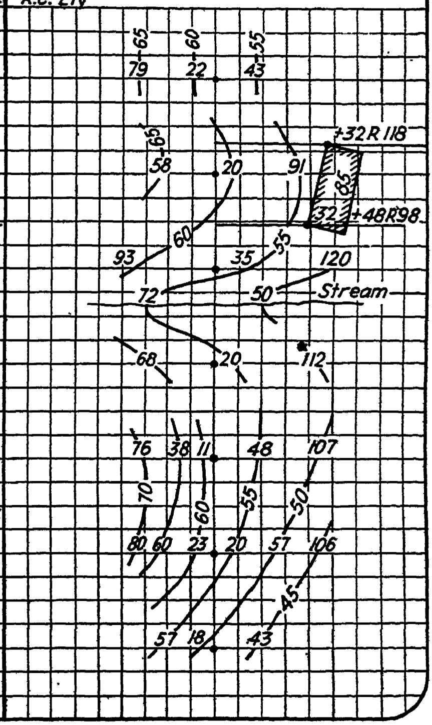


FIG. 21.—Portion of route-survey field notes. The notes shown, on the right-hand page are often kept in a large, separate field book.

358. Procedure for Route Surveys (see Fig. 21). A traverse is established near the center line of the strip, stations are marked at every 100 feet, and the ground elevations are determined at every station by profile leveling. Topographical features are located by plus and offset, estimated right angles being used. The offsets to the contour lines are determined at regular intervals (often at every station) and wherever else necessary by finding the actual contour lines on the ground with the aid of a **hand level** and measuring the offsets with a metallic tape.

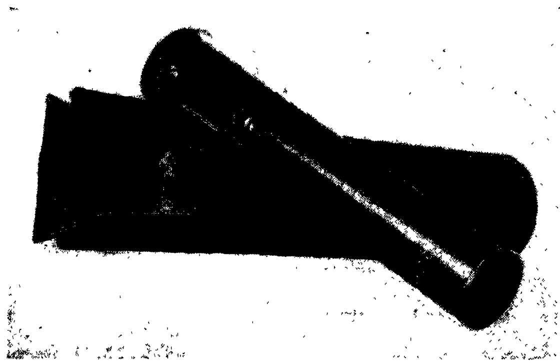
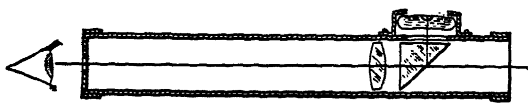
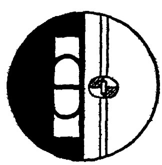


FIG. 22.—Hand level and case. (*W. & L. E. Gurley.*)



The lens and prism cover only half of the tube



View through the hand level showing the appearance of the rod target when it has been placed at the same elevation as the instrument

FIG. 23.—Operation of the hand level.

359. The Hand Level. Figures 22 and 23 show the appearance and operation of a hand level. The instrument is adjusted so that when the bubble is centered, the line of sight is horizontal. There is a mark on the bubble tube on which the bubble is centered, and the reflection of this line, together with the peephole, determines the line of sight. The instrument can be held in the hand and the bubble centered while the position of the line of sight on the rod is observed. Owing to the unsteady support, magnification is not helpful, and therefore a telescope is seldom incorporated. The levelman can seldom read the rod, and therefore a target is used. The rodman adjusts the rod at the direction of the levelman and then reads its

position. The levelman must be careful to keep the instrument at the same height between plus and minus sights. The accuracy is about 3 feet $\sqrt{\text{miles}}$. The level is used in a special way for determining contours in a route survey.

360. Locating Contours with a Hand Level. Usually the position of each contour is found along a line perpendicular to the traverse at each station (see Fig. 24). An example is given of this procedure when used for locating 5-foot contours.

The hand level is placed on a forked stick cut so that the line of sight is 5 feet from the ground. To work downhill the stick is first placed on the ground at the station. Assume that from the profile notes it is known that the station has the elevation 92.3 feet. The H.I. is 97.3. To find the 90-foot contour the rod target is set at 7.3 and the rod moved downhill perpendicular to the traverse line until the target is at the level of the instrument. The offset is then measured from the station.

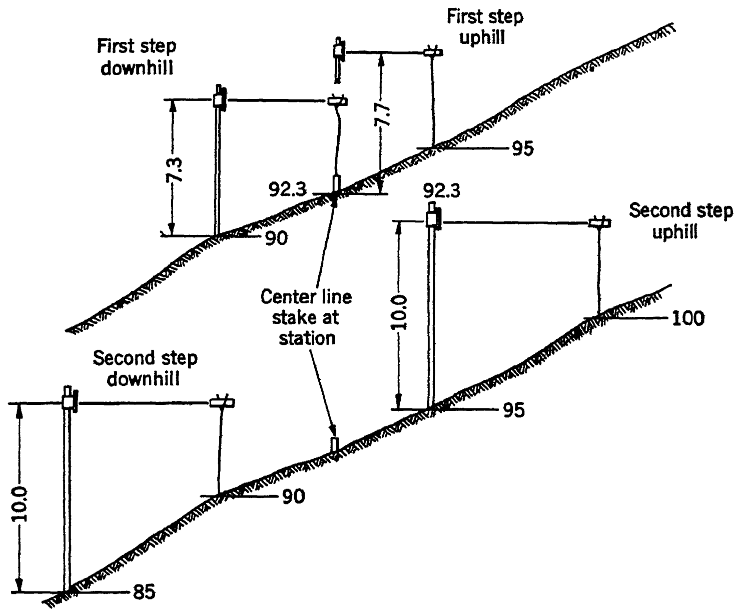


FIG. 24.—Finding the contour lines with the hand level.

The target is then set at 10 feet, the level is moved to the position of the rod, and the process is repeated to find the 85-foot contour, etc.

In working uphill the rod is first held at the station with the target set at 7.7. The instrument is moved uphill until it is level with the target. The instrument is then on ground 2.7 feet above the station and therefore at the 95-foot contour. The offset is measured. The target is set at 10 feet, the rod moved to the instrument position, and the process repeated to find the 100-foot contour, etc.

Usually the results are plotted in the field book and the contours between stations are sketched in while the ground is being viewed.

PROBLEMS

1. Copy Fig. 25 approximately to scale, making a rectangle $5\frac{1}{4}$ by $7\frac{1}{2}$ inches. Draw the 5-foot contour lines. First interpolate along streams.

2. From the stadia notes in Fig. 26, draw a map to the scale of 1 in. = 200 ft.

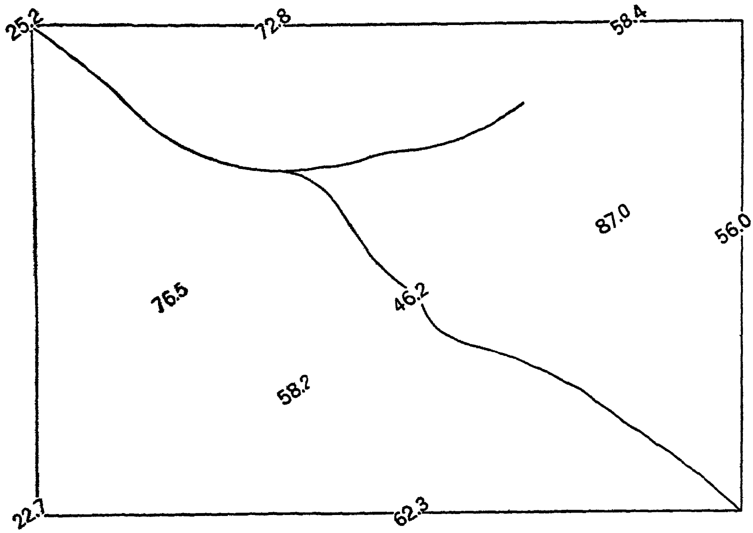


FIG. 25.—Problem for contour interpolation.

MILL SITE SURVEY
f + c = 1.00

Ch. Smith — Date
π Jones — Hot, Calm
Rod Cole

Sta	S	Azim	V ∠	H	V	Elev.	
π A	h. i.	4.38					On Rock in Stream
E	6.08	260°32′	+ 1°41′				
B	9.00	0°00′	+ 2°10′				
	1.79	180°00′	+ 2°18′				Property Corner
π B	h. i.	4.63					
A	9.00	180°00′	− 2°10′				
C	9.04	276°20′	− 1°14′				
	5.67	223°25′	− 2°24′				Saddle
	3.47	287°02′	− 5°56′				℄ Stream
	.99	0°00′	− 0°17′				Property Corner
π C	h. i.	4.71					Property Corner
B	9.06	96°20′	+ 1°14′				
D	7.07	171°52′	+ 1°04′				
π D	h. i.	4.22					
C	7.05	351°52′	− 1°02′				
E	4.46	153°26′	− 1°14′				
1	1.57	71°20′	− 3°40′				
2	2.60	104°40′	− 2°38′				
	1.06	290°15′	+ 1°48′				
π E	h. i.	4.68					
D	4.46	333°26′	+ 1°14′				
A	6.06	80°32′	− 1°41′				
B.M.	3.11	255°17′	+ 0°19′			67.43	Mon at Property Cor.

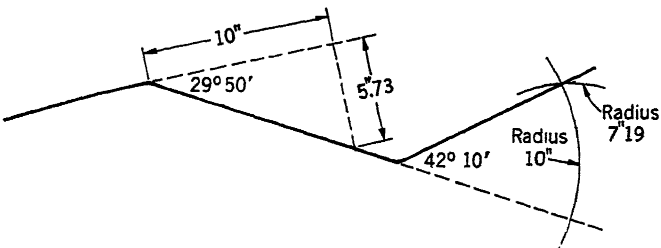
FIG. 26.—Example of stadia notes.

CHAPTER XIV

DRAWING MAPS AND KEEPING RECORDS

MAPPING

361. Maps. Maps have many uses and are made accordingly. When maps are to be used for design, it must be possible to determine distances, elevations, and angles from them by scaling. Usually the entire map must have a uniform standard of accuracy so that these data may be determined anywhere on it with equally accurate results.



From table of tangents
Tangent 29° 50′ = 5.7348

From table of chords
Chord for 42° 10′ = 0.71946

FIG. 1.—Plotting angles by tangents or chords.

Since the survey on which a map is based can be readily made more accurate than can any drafting procedure, map accuracy is limited by the accuracy of drafting. This imposes a high standard on the drafting technique required, and special methods must be employed. Steel straightedges must be used for important lines, important positions must be pricked with a needle, and important directions must be established by precise linear scaling. The T-square and wooden-edged drawing board cannot be relied on for drawing parallel lines, and any parallel or angular drafting equipment must be tested thoroughly before it can be safely adopted.

362. When less precision is desired, methods of plotting will occur to the reader. When coordinates are not computed, angles can be plotted by protractor or by setting out tangents or chords (see Fig. 1) and lengths can be scaled directly. Only precise methods are covered in the following paragraphs.

363. Steps in Making a Map. The procedure for mapping is as follows:

1. Determine the types of features to be included.
2. Draw an approximate small-scale sketch of the area to be included in the map.
3. Establish the scale.
4. Establish the size of the map sheets.
5. Determine the arrangement of the map.
6. Construct the grid (the graticule).
7. Plot the control.
8. Plot features.
9. Add details.
10. Ink.

364. Features to Be Included in the Map. Article 325 describes the features often included in a map. The features chosen, of course, depend on the purpose of the map and are usually stipulated before the survey is begun. Ordinarily all data obtained by the survey are included; for the cost of the survey is high, and maps are often used for purposes never considered when they were made. Data are sometimes omitted to avoid confusion.

Four items, independent of the survey, should **always** be included. They are

1. Statement of scale.
2. Graphical indication of scale in case the sheet shrinks or expands.
3. Title.
4. North point even if very approximate.

Whenever it is necessary to give lengths or elevations to an accuracy greater than shown graphically, the values are lettered on the map near the features they represent.

365. The Approximate Sketch. Before the map can be started, the arrangement of the map must be planned—if only to keep all of the map on the paper. To plan the map a small-scale sketch of the outline of the map must be obtained. Usually a sketch is made of the perimeter of the control system and the controlling external topographic observations. Sometimes the outline can be sketched by memory on an existing map (see Fig. 2).

366. Choice of Map Scale. Three types of map scales are in common use. They are generally known as **engineer's scales, architect's scales,** and **ratio scales.** An engineer's scale gives the number of feet represented by 1 inch on the map and is written **1 in. = 20 ft** or **1 in. = 100 ft,** etc. An architect's scales gives the fraction of an inch on the map that represents one foot and is written **⅛ in. = 1 ft,**

$\frac{1}{16}$ **in. = 1 ft,** etc. A ratio scale gives the relative size of a distance on the map to the represented distance on the ground and is written, 1:20,000, 1:62,500, etc.

The engineer's scale is the most convenient for mapping limited areas and is the most generally used. Rules for engineer's scales are usually made with the following number of spaces per inch: 10, 20, 30, 40, 50, 60. Eighty graduations per inch are sometimes found. Map scales are selected accordingly. The most common are 1 in. = 20, 40, 50, 100, 200, 500, 1,000, and 2,000 ft.

The map scale chosen should be the smallest at which the desired precision can be obtained. It is generally assumed that distances on a map can be measured to $\frac{1}{50}$ inch. Thus, if distances are required to the nearest 0.4 foot, 0.4 foot should be represented by $\frac{1}{50}$ inch on the map

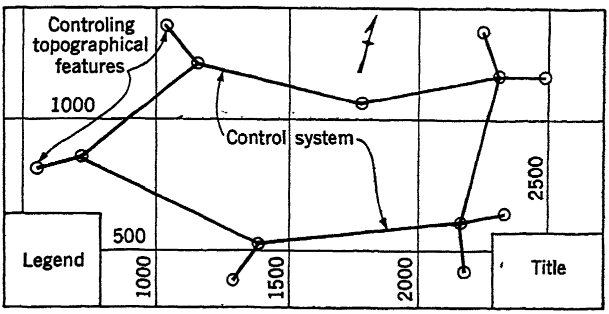


Fig. 2.—Sketch map with sheet arrangement completed.

and the map scale would be 1 in. = 20 ft. In like manner, if distances are required to the nearest 10 feet, the scale should be 1 in. = 500 ft.

For large areas, the entire survey is planned according to the desired map accuracy. For example, if the largest distance in the area covered is 5,000 feet and it is necessary to scale to the nearest foot, the maximum error allowed in the survey would be ± 0.5 foot. Accordingly, the control system should have a minimum accuracy of 1:10,000, i.e., 0.5/5,000, and the ties should be made to the nearest half foot. Stadia measurements (having an accuracy of 1:300) should not be made over 150 feet long. With such limits it might, of course, be theoretically possible to find distances on the map that were in error by 2 feet, but the limits described are usually accepted, for the adjustment of control and the laws of chance would practically eliminate the possibility of this occurrence.

Within small areas it is difficult to make a well-planned survey that does not give position within the mapping accuracy desired.

When a map is to be traced for blueprinting, the scale must often be

increased so that small details can be shown in the wider ink lines required.

367. The Size of Map Sheets. If a standard size of sheet is not required, the map should be drawn on one sheet if possible. The difficulty of using more than one sheet is so great that sheets as large as 40 by 60 inches are used. They are hard to file, but they can be used on a drawing board. The sheets must be large enough to include a minimum border of ½ inch to protect the map. Larger borders give a better appearance. Space must be reserved for the title and any required legends. Frequently, when small working sheets are required, the original map is drawn on a large sheet but traced in small sections.

368. The Arrangement of the Map. The border lines adopted should be drawn to scale on the sketch of the area (see Figs. 2, 3). Some-

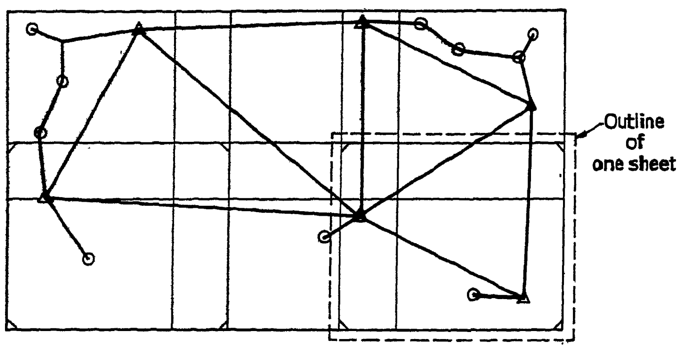


FIG. 3.—Sketch map with overlapping sheet arrangement completed.

times a considerable overlap is used so that parts of the map appear on more than one sheet as in Fig. 3. When map sheets overlap, the coordinate grid shows how the sections are matched. Match lines must be used if no grid is drawn. Sometimes the borders are oriented to the north of the coordinate system, and sometimes they are placed at coordinate lines having round-number values.

369. The Grid. The coordinate system is shown on the map by a **graticule** of lines parallel to the axes, 5 to 10 inches apart (for ease in plotting) and representing round-number coordinate values. The approximate position of this grid system is found by scaling from the border lines on the sketch. The grid system can be laid out with a T square and triangle; but if an accurate grid is desired, an accurate right angle should be established and all lines thereafter laid out by scaling. This procedure requires a steel straightedge but no other precise drafting instrument other than the scale.

Figure 4 illustrates the method. Line 1 is placed by scaling the distances $S1$ and $S2$ on the sketch, and A is placed by scaling $S3$. The right angle at A is established by trial and error, the 3, 4, 5 method being used. Measuring from A, points are pricked along lines 1 and 2 according to the required spacing of the grid lines. Point D is located by trial measurements from B and C. Lines 3 and 4 are divided by prick marks, and finally opposite prick points are connected to form the grid.

All lines must be drawn with a very hard pencil sharpened to a round point and held against the bottom of the steel straightedge. Points must be pricked with a needle. After the grid is constructed, the spacing should be thoroughly checked with dividers.

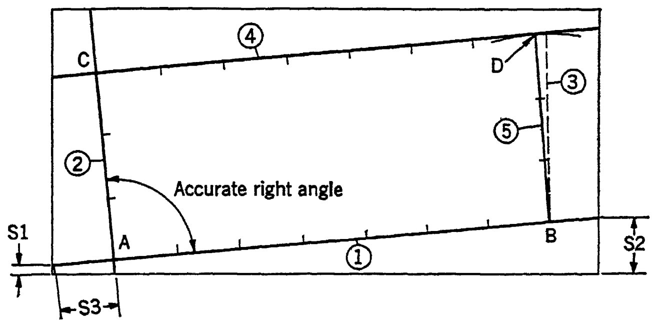


FIG. 4.—Establishing an accurate grid. S_1 and S_2 are scaled from the sketch. Line 1 is drawn. $S3$ is scaled from the sketch and line 2 erected at exactly 90 deg. Point D is found by trial measurements from B and C.

370. Plotting Control. The control should be plotted by coordinates, measuring from the grid lines. The stations thus plotted are connected by lines representing the traverse or triangulation system, and their lengths and the angles between them are checked by protractor and scale against the **original field notes.** This check will disclose nearly all blunders and should never be omitted.

When the coordinates of control stations are not computed, at least the directions of the lines should be computed. Lines plotted by directions are not affected by the accumulated accidental errors caused by plotting successive angles.

371. Plotting Features. Stadia traverses and the positions of topographical features are plotted by protractor and scale, measuring from the control system. A drafting machine (Fig. 5) or a large paper protractor used as shown in Fig. 6 will be found to be a timesaver. Unless the drafting machine is quite accurate, the angular scale should be oriented at each station.

372. The Title. In the past, maps were often embellished with considerable artistry. Too frequently, however, the ornamentation covered lack of data. Today, some survival of this custom is found in

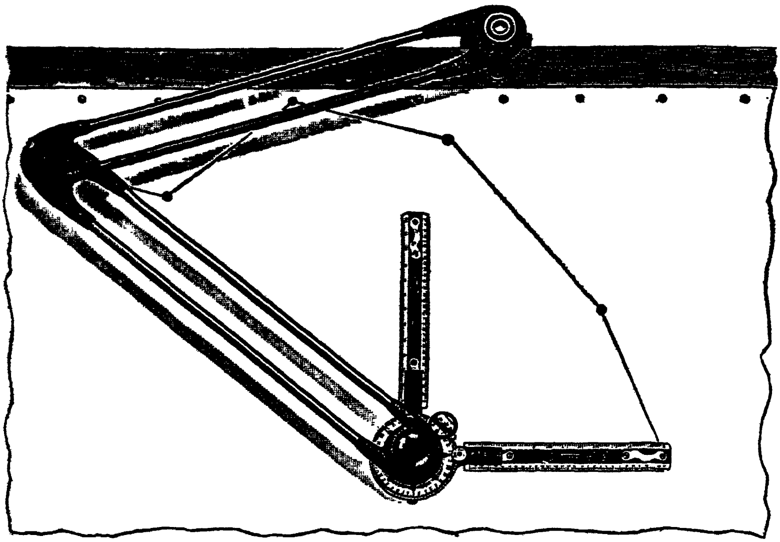


FIG. 5.—A Keuffel & Esser drafting machine. (*Keuffel & Esser Co.*)

ornate titles and other details. There may be some justification for them when the map is made for a private individual. Otherwise, the title and other details should be designed to give the maximum information at a glance. The title should contain the following items unless a good reason exists for their omission. They are stated in the usual order found in titles.

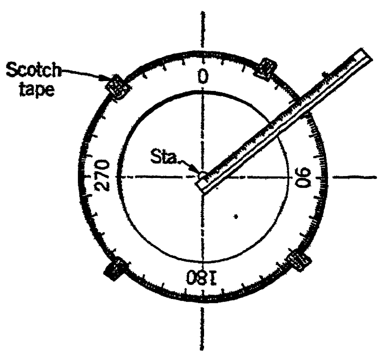


FIG. 6.—Plotting topography by scale and cutout paper protractor.

1. Organization making the map.
2. Technical name (map, chart, or plan).
3. Name of the area mapped.
4. Name of purchaser.
5. Where area is located.
6. Name of engineer responsible.
7. Date of survey.
8. Scale.
9. Identification numbers.

Frequently this complete list will result in duplication, and certain items should be omitted.

Certain items should be emphasized by larger and heavier letters so that the map can be quickly selected from others. The order of emphasis should be the following:

Greatest emphasis, items 2, 3, 4.
Medium emphasis, items 1, 5, 6.
Least emphasis, items 7, 8, 9.

JONES AND JONES CONSULTANTS

MAP

OF THE

SITE OF PROPOSED PLANT B

OF THE

SMITH MANUFACTURING CO.

LAKEVILLE, NEW YORK

MAY 3, 1947 SCALE 1 INCH=200 FEET

Fig. 7.

Examples of the same title used for different purposes are shown in Figs. 7 and 8. Figure 7 shows the kind of title that would be used by a consulting firm preparing the map for a manufacturing company. The simple form of title shown in Fig. 8 would be used by the manufacturing company when the map was prepared by their own personnel.

THE SMITH MANUFACTURING CO.

Map of Site of Plant B
Lakeville, New York

Survey by: Thomas Smith *May 3, 1947*
Scale: 1-Inch = 200 feet *D'w'g. 2222*

Fig. 8.

It will be found that vertical letters are more quickly read than slant letters. Roman type offers the best method of emphasis. Figure 9 gives useful alphabets.

373. Other Details. Figure 10 gives a good form of graphical scale. A graphical scale should be as long as possible within reason. It can be omitted if a coordinate grid is used. A typical north point is shown in

A B C D E F G H I J K L M

N O P Q R S T U V W X Y Z

a b c d e f g h i j k l m n o p q r s

t u v w x y z & 1 2 3 4 5 6 7 8 9 0

A B C D E F G H I J K L M

N O P Q R S T U V W X Y Z

a b c d e f g h i j k l m n o p q r s

t u v w x y z & 1 2 3 4 5 6 7 8 9 0

FIG. 9.

A B C D E F G H I J

K L M N O P Q R S T

U V W X Y Z a b c d e f

g h i j k l m n o p q r s t u v

w x y z & 1 2 3 4 5 6 7 8 9 0

A B C D E F G H I J

K L M N O P Q R S T

U V W X Y Z a b c d e f

g h i j k l m n o p q r s t u v

w x y z & 1 2 3 4 5 6 7 8 9 0

Fig. 11. Beside it should be a legend stating exactly whether it is true, magnetic, or assumed. Spot elevations and dimensions should be printed at the features to which they refer. Descriptive legends are often valuable aids to clarity. They are usually placed at the lower left-hand corner of the map.

374. Topographic Symbols. Figure 12 shows the most useful typical topographic symbols. They are essential for small-scale maps

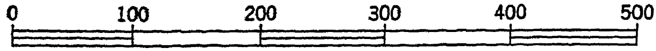


FIG. 10.—A graphical scale.

where the features are small and detailed. A legend giving their meaning should accompany the map. On large-scale maps the features can usually be recognized and are easily labeled. The symbols are useful for outlining the limits of woods, swamps, etc.

375. Inking the Original Map. The entire original map should be inked, including the coordinate grid and the survey control system. The identification numbers or letters and the coordinates of control

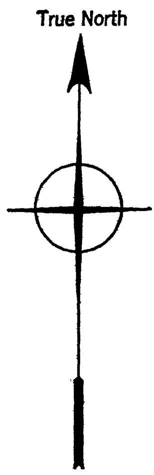


FIG. 11.—A north point.

stations, the identifications and elevations of bench marks, the azimuths, and sometimes the lengths of lines should be printed in appropriate places. This information will prove of great assistance when additions to the map are required and when location surveys are necessary.

All control lines on the original map should be inked with very fine lines for accuracy and clarity. In general, fine lines are preferable except when emphasis is necessary. Often colored inks improve the appearance

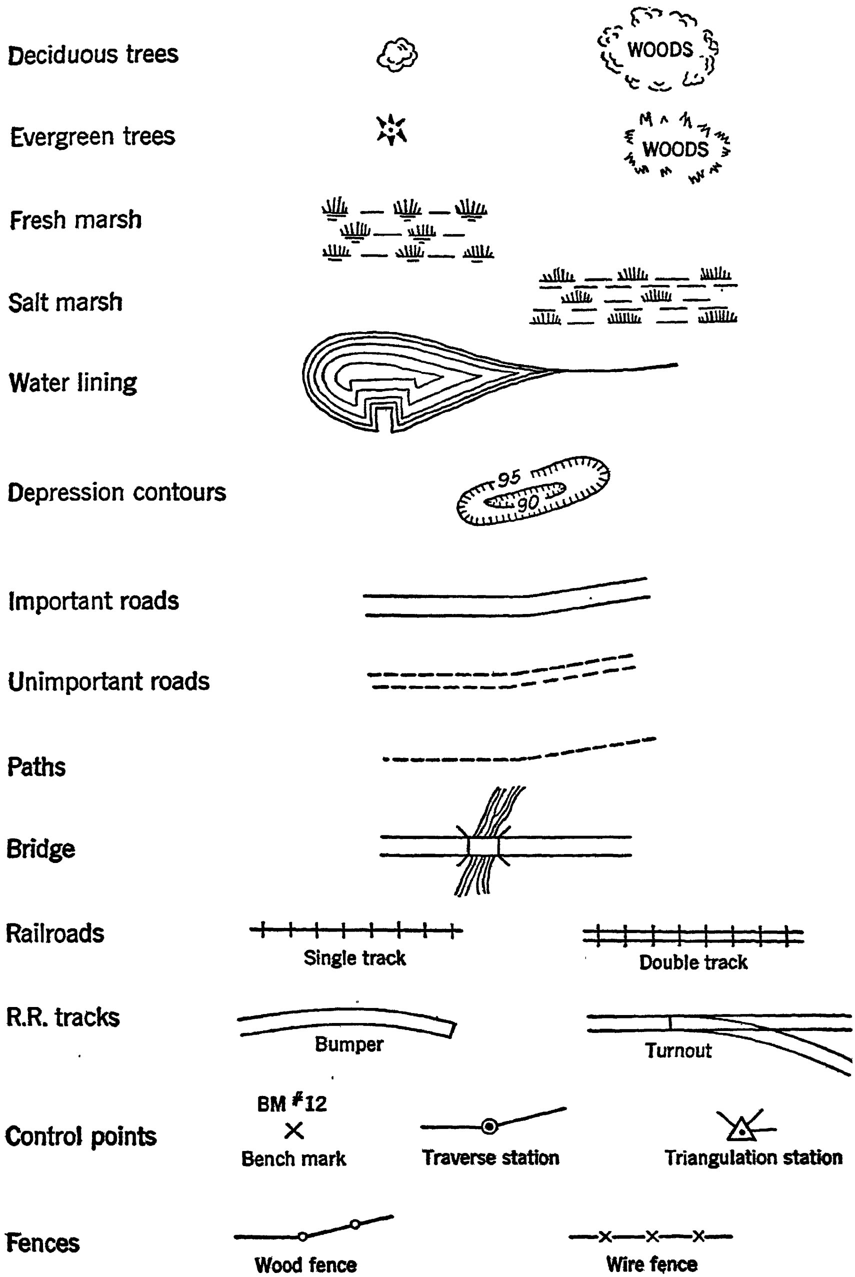


FIG. 12.—Topographic symbols.

and legibility. The following schedule is representative of standard practice in the use of colors.

1. Culture (works of man)	Black
2. Water	Blue
3. Relief (including contour lines)	Brown
4. Survey points and lines	Red

376. Tracing. Tracings can never reach the accuracy of the original map and are almost always made for a special purpose. Usually, therefore, only the items and those parts of the map which are necessary to the purpose are traced, and heavy lines are used freely for emphasis. A graphical scale should be included, or the coordinate intersections should be shown by crosses to give scale, for both the tracing cloth and the blueprint change considerably in size from day to day.

RECORDS

377. Importance of Survey Records. Since survey data are invariably used for many purposes in addition to the specific purpose for which they were obtained, survey records are very valuable and should be preserved with great care.

378. Job Names. Every job must be given a name at the outset of the work. Methods of naming differ with the size of the organization and its functions. Usually the name of the purchaser or a **job number** is used. The job name must appear on all records except the records of the survey control points, for which it has no significance.

379. Records of Control Points. Control points nearly always have a continuing value. Each should be given a number for indentification. A card index should be kept, with a card for each control point containing a description of the point, a sketch showing its position, including **witness** measurements to various near-by objects, and the coordinates or the elevations it represents. The cards, of course, are filed by number.

380. Field-book Records. The field books should be used chronologically and numbered and paged as they are issued to the field parties. The name or number of each job, the date, the members of the field party, and the weather should be recorded daily. Field books are filed by number.

381. The Computation Record. The computations should show the name or number of the job, the field-book number and page, and the date of computation. They are usually filed by job name or number.

382. The Map References. The map shows the name of the job, the date of the survey, and the field-book number and page. Maps are filed by job name or number.

383. Survey Index Cards. Since maps are hard to handle and often no map results from a survey, a card for each survey should be made that duplicates the references on the map or carries the same type of information when no map exists. Like maps they are filed by job name or number.

384. The Index. A good index should originate with the item in the record most easily brought to mind. Accordingly, a survey index **must** originate with the location of the survey. By far the best index is an outline map of the areas where surveys are performed. On the outline map are placed, in their proper positions, the control points with their numbers, the job names and dates, and the field-book numbers and pages.

385. Method of Finding the Records. With the system outlined above the survey records can be found according to the table below:

Known	Index	References to
Location..................	Outline map	Job name or number, field book, date, control points
Job name or number.......	Survey cards or map	Location, field book, date, computations
Date..	Field book	Location, job name

TABLE I[1]

COMMON LOGARITHMS OF NUMBERS

This table gives the common logarithms, to five places of decimals, of numbers from 1 to 10,000 and, to seven places of decimals, of numbers from 10,000 to 11,000. Throughout the first part of the table, on any pair of open pages, are found the proportional parts (Prop. Parts) of the tabular differences that occur on these pages. Interpolation is facilitated by the use of proportional parts as shown in the examples below.

Example 1. To find the logarithm of the number 33207. From the main table, the logarithm of 33200 is 52114 and the tabular difference is 13. In the table of proportional parts headed 13, beside the number 7, is found the increment 9.1. Adding 9.1 to 52114 gives the value sought, 52123.

Example 2. To find the number having the logarithm 52123. In the main table, the logarithm just less than 52123 is 52114, which is the logarithm of 33200. The tabular difference is 13. Subtracting from 52123, the value 52114, gives the increment 9. The nearest increment to 9 in the table of proportional parts headed 13 is 9.1, which is beside the number 7. Adding 7 to 33200 gives the value sought, 33207.

[1] From "Plane and Spherical Trigonometry," by Claude I. Palmer and Charles W. Leigh; used by permission of the publishers, McGraw-Hill Book Company, Inc., New York.

N.	L.	0	1	2	3	4	5	6	7	8	9
100	00	000	043	087	130	173	217	260	303	346	389
101		432	475	518	561	604	647	689	732	775	817
102		860	903	945	988	*030	*072	*115	*157	*199	*242
103	01	284	326	368	410	452	494	536	578	620	662
104		703	745	787	828	870	912	953	995	*036	*078
105	02	119	160	202	243	284	325	366	407	449	490
106		531	572	612	653	694	735	776	816	857	898
107		938	979	*019	*060	*100	*141	*181	*222	*262	*302
108	03	342	383	423	463	503	543	583	623	663	703
109		743	782	822	862	902	941	981	*021	*060	*100
110	04	139	179	218	258	297	336	376	415	454	493
111		532	571	610	650	689	727	766	805	844	883
112		922	961	999	*038	*077	*115	*154	*192	*231	*269
113	05	308	346	385	423	461	500	538	576	614	652
114		690	729	767	805	843	881	918	956	994	*032
115	06	070	108	145	183	221	258	296	333	371	408
116		446	483	521	558	595	633	670	707	744	781
117		819	856	893	930	967	*004	*041	*078	*115	*151
118	07	188	225	262	298	335	372	408	445	482	518
119		555	591	628	664	700	737	773	809	846	882
120		918	954	990	*027	*063	*099	*135	*171	*207	*243
121	08	279	314	350	386	422	458	493	529	565	600
122		636	672	707	743	778	814	849	884	920	955
123		991	*026	*061	*096	*132	*167	*202	*237	*272	*307
124	09	342	377	412	447	482	517	552	587	621	656
125		691	726	760	795	830	864	899	934	968	*003
126	10	037	072	106	140	175	209	243	278	312	346
127		380	415	449	483	517	551	585	619	653	687
128		721	755	789	823	857	890	924	958	992	*025
129	11	059	093	126	160	193	227	261	294	327	361
130		394	428	461	494	528	561	594	628	661	694
131		727	760	793	826	860	893	926	959	992	*024
132	12	057	090	123	156	189	222	254	287	320	352
133		385	418	450	483	516	548	581	613	646	678
134		710	743	775	808	840	872	905	937	969	*001
135	13	033	066	098	130	162	194	226	258	290	322
136		354	386	418	450	481	513	545	577	609	640
137		672	704	735	767	799	830	862	893	925	956
138		988	*019	*051	*082	*114	*145	*176	*208	*239	*270
139	14	301	333	364	395	426	457	489	520	551	582
140		613	644	675	706	737	768	799	829	860	891
141		922	953	983	*014	*045	*076	*106	*137	*168	*198
142	15	229	259	290	320	351	381	412	442	473	503
143		534	564	594	625	655	685	715	746	776	806
144		836	866	897	927	957	987	*017	*047	*077	*107
145	16	137	167	197	227	256	286	316	346	376	406
146		435	465	495	524	554	584	613	643	673	702
147		732	761	791	820	850	879	909	938	967	997
148	17	026	056	085	114	143	173	202	231	260	289
149		319	348	377	406	435	464	493	522	551	580
150		609	638	667	696	725	754	782	811	840	869
N.	L.	0	1	2	3	4	5	6	7	8	9

Prop. Parts

	44	43	42
1	4.4	4.3	4.2
2	8.8	8.6	8.4
3	13.2	12.9	12.6
4	17.6	17.2	16.8
5	22.0	21.5	21.0
6	26.4	25.8	25.2
7	30.8	30.1	29.4
8	35.2	34.4	33.6
9	39.6	38.7	37.8

	41	40	39
1	4.1	4.0	3.9
2	8.2	8.0	7.8
3	12.3	12.0	11.7
4	16.4	16.0	15.6
5	20.5	20.0	19.5
6	24.6	24.0	23.4
7	28.7	28.0	27.3
8	32.8	32.0	31.2
9	36.9	36.0	35.1

	38	37	36
1	3.8	3.7	3.6
2	7.6	7.4	7.2
3	11.4	11.1	10.8
4	15.2	14.8	14.4
5	19.0	18.5	18.0
6	22.8	22.2	21.6
7	26.6	25.9	25.2
8	30.4	29.6	28.8
9	34.2	33.3	32.4

	35	34	33
1	3.5	3.4	3.3
2	7.0	6.8	6.6
3	10.5	10.2	9.9
4	14.0	13.6	13.2
5	17.5	17.0	16.5
6	21.0	20.4	19.8
7	24.5	23.8	23.1
8	28.0	27.2	26.4
9	31.5	30.6	29.7

	32	31	30
1	3.2	3.1	3.0
2	6.4	6.2	6.0
3	9.6	9.3	9.0
4	12.8	12.4	12.0
5	16.0	15.5	15.0
6	19.2	18.6	18.0
7	22.4	21.7	21.0
8	25.6	24.8	24.0
9	28.8	27.9	27.0

0	1′	=	60″	S. 4.68 557	T. 4.68 557
0	2	=	120	557	557
0	3	=	180	557	557
0	16	=	960	557	558
0	17	=	1020	557	558
0	18	=	1080	557	558
0°	19′	=	1140″	S. 4.68 557	T. 4.68 558
0	20	=	1200	557	558
0	21	=	1260	557	558
0	22	=	1320	557	558
0	23	=	1380	557	558
0	24	=	1440	557	558
0	25	=	1500	557	558

N.	L.	0	1	2	3	4	5	6	7	8	9
150	17	609	638	667	696	725	754	782	811	840	869
151		898	926	955	984	*013	*041	*070	*099	*127	*156
152	18	184	213	241	270	298	327	355	384	412	441
153		469	498	526	554	583	611	639	667	696	724
154		752	780	808	837	865	893	921	949	977	*005
155	19	033	061	089	117	145	173	201	229	257	285
156		312	340	368	396	424	451	479	507	535	562
157		590	618	645	673	700	728	756	783	811	838
158		866	893	921	948	976	*003	*030	*058	*085	*112
159	20	140	167	194	222	249	276	303	330	358	385
160		412	439	466	493	520	548	575	602	629	656
161		683	710	737	763	790	817	844	871	898	925
162		952	978	*005	*032	*059	*085	*112	*139	*165	*192
163	21	219	245	272	299	325	352	378	405	431	458
164		484	511	537	564	590	617	643	669	696	722
165		748	775	801	827	854	880	906	932	958	985
166	22	011	037	063	089	115	141	167	194	220	246
167		272	298	324	350	376	401	427	453	479	505
168		531	557	583	608	634	660	686	712	737	763
169		789	814	840	866	891	917	943	968	994	*019
170	23	045	070	096	121	147	172	198	223	249	274
171		300	325	350	376	401	426	452	477	502	528
172		553	578	603	629	654	679	704	729	754	779
173		805	830	855	880	905	930	955	980	*005	*030
174	24	055	080	105	130	155	180	204	229	254	279
175		304	329	353	378	403	428	452	477	502	527
176		551	576	601	625	650	674	699	724	748	773
177		797	822	846	871	895	920	944	969	993	*018
178	25	042	066	091	115	139	164	188	212	237	261
179		285	310	334	358	382	406	431	455	479	503
180		527	551	575	600	624	648	672	696	720	744
181		768	792	816	840	864	888	912	935	959	983
182	26	007	031	055	079	102	126	150	174	198	221
183		245	269	293	316	340	364	387	411	435	458
184		482	505	529	553	576	600	623	647	670	694
185		717	741	764	788	811	834	858	881	905	928
186		951	975	998	*021	*045	*068	*091	*114	*138	*161
187	27	184	207	231	254	277	300	323	346	370	393
188		416	439	462	485	508	531	554	577	600	623
189		646	669	692	715	738	761	784	807	830	852
190		875	898	921	944	967	989	*012	*035	*058	*081
191	28	103	126	149	171	194	217	240	262	285	307
192		330	353	375	398	421	443	466	488	511	533
193		556	578	601	623	646	668	691	713	735	758
194		780	803	825	847	870	892	914	937	959	981
195	29	003	026	048	070	092	115	137	159	181	203
196		226	248	270	292	314	336	358	380	403	425
197		447	469	491	513	535	557	579	601	623	645
198		667	688	710	732	754	776	798	820	842	863
199		885	907	929	951	973	994	*016	*038	*060	*081
200	30	103	125	146	168	190	211	233	255	276	298
N.	L.	0	1	2	3	4	5	6	7	8	9

Prop. Parts

	29	28	27	26	25	24	23	22	21
1	2.9	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.1
2	5.8	5.6	5.4	5.2	5.0	4.8	4.6	4.4	4.2
3	8.7	8.4	8.1	7.8	7.5	7.2	6.9	6.6	6.3
4	11.6	11.2	10.8	10.4	10.0	9.6	9.2	8.8	8.4
5	14.5	14.0	13.5	13.0	12.5	12.0	11.5	11.0	10.5
6	17.4	16.8	16.2	15.6	15.0	14.4	13.8	13.2	12.6
7	20.3	19.6	18.9	18.2	17.5	16.8	16.1	15.4	14.7
8	23.2	22.4	21.6	20.8	20.0	19.2	18.4	17.6	16.8
9	26.1	25.2	24.3	23.4	22.5	21.6	20.7	19.8	18.9

0° 2′ = 120″	S. 4.68 557	T. 4.68 557
0 3 = 180	557	557
0 4 = 240	557	558
0 25 = 1500	557	558
0 26 = 1560	557	558
0 27 = 1620	557	558
0° 28′ = 1680″	S. 4.68 557	T. 4.68 558
0 29 = 1740	557	559
0 30 = 1800	557	559
0 31 = 1860	557	559
0 32 = 1920	557	559
0 33 = 1980	557	559
0 34 = 2040	557	559

N.	L. 0	1	2	3	4	5	6	7	8	9
200	30 103	125̄	146	168	190	211	233	255̄	276	298
201	320	341	363	384	406	428	449	471	492	514
202	535	557	578	600	621	643	664	685	707	728
203	75̄0	771	792	814	835	856	878	899	920	942
204	963	984	*006	*027	*048	*069	*091	*112	*133	*154
205	31 175	197	218	239	260	281	302	323	345̄	366
206	387	408	429	45̄0	471	492	513	534	555̄	576
207	597	618	639	660	681	702	723	744	765̄	785
208	806	827	848	869	890	911	931	952	973	994
209	32 015̄	035	056	077	098	118	139	160	181	201
210	222	243	263	284	305̄	325	346	366	387	408
211	428	449	469	490	510	531	552	572	593	613
212	634	654	675̄	695̄	715	736	756	777	797	818
213	838	858	879	899	919	940	960	980	*001	*021
214	33 041	062	082	102	122	143	163	183	203	224
215	244	264	284	304	325̄	345̄	365̄	385	405	425
216	445	465	486	506	526	546	566	586	606	626
217	646	666	686	706	726	746	766	786	806	826
218	846	866	885	905	925	945	965	985̄	*005̄	*025̄
219	34 044	064	084	104	124	143	163	183	203	223
220	242	262	282	301	321	341	361	380	400	420
221	439	459	479	498	518	537	557	577	596	616
222	635	655̄	674	694	713	733	753	772	792	811
223	830	85̄0	869	889	908	928	947	967	986	*005
224	35 025̄	044	064	083	102	122	141	160	180	199
225	218	238	257	276	295	315̄	334	353	372	392
226	411	430	449	468	488	507	526	545	564	583
227	603	622	641	660	679	698	717	736	755	774
228	793	813	832	851	870	889	908	927	946	965̄
229	984	*003	*021	*040	*059	*078	*097	*116	*135	*154
230	36 173	192	211	229	248	267	286	305̄	324	342
231	361	380	399	418	436	455	474	493	511	530
232	549	568	586	605̄	624	642	661	680	698	717
233	736	754	773	791	810	829	847	866	884	903
234	922	940	959	977	996	*014	*033	*051	*070	*088
235	37 107	125	144	162	181	199	218	236	254	273
236	291	310	328	346	365̄	383	401	420	438	457
237	475̄	493	511	530	548	566	585̄	603	621	639
238	658	676	694	712	731	749	767	785	803	822
239	840	858	876	894	912	931	949	967	985̄	*003
240	38 021	039	057	075	093	112	130	148	166	184
241	202	220	238	256	274	292	310	328	346	364
242	382	399	417	435	453	471	489	507	525̄	543
243	561	578	596	614	632	65̄0	668	686	703	721
244	739	757	775̄	792	810	828	846	863	881	899
245	917	934	952	970	987	*005	*023	*041	*058	*076
246	39 094	111	129	146	164	182	199	217	235̄	252
247	270	287	305̄	322	340	358	375	393	410	428
248	445	463	480	498	515	533	550	568	585	602
249	620	637	655̄	672	690	707	724	742	759	777
250	794	811	829	846	863	881	898	915	933	950
N.	L. 0	1	2	3	4	5	6	7	8	9

Prop. Parts

	22	21
1	2.2	2.1
2	4.4	4.2
3	6.6	6.3
4	8.8	8.4
5	11.0	10.5
6	13.2	12.6
7	15.4	14.7
8	17.6	16.8
9	19.8	18.9

	20
1	2.0
2	4.0
3	6.0
4	8.0
5	10.0
6	12.0
7	14.0
8	16.0
9	18.0

	19
1	1.9
2	3.8
3	5.7
4	7.6
5	9.5
6	11.4
7	13.3
8	15.2
9	17.1

	18
1	1.8
2	3.6
3	5.4
4	7.2
5	9.0
6	10.8
7	12.6
8	14.4
9	16.2

	17
1	1.7
2	3.4
3	5.1
4	6.8
5	8.5
6	10.2
7	11.9
8	13.6
9	15.3

Prop. Parts

0°	3′ = 180″	S. 4.68 557	T. 4.68 557
0	4 = 240	557	558
0	5 = 300	557	558
0	33 = 1980	557	559
0	34 = 2040	557	559
0	35 = 2100	557	559

0°	36′ = 2160″	S. 4.68 557	T. 4.68 559
0	37 = 2220	557	559
0	38 = 2280	557	559
0	39 = 2340	557	559
0	40 = 2400	557	559
0	41 = 2460	556	560
0	42 = 2520	556	560

N.	L. 0	1	2	3	4	5	6	7	8	9
250	39 794	811	829	846	863	881	898	915	933	950
251	967	98$\bar{5}$	*002	*019	*037	*054	*071	*088	*106	*123
252	40 140	157	17$\bar{5}$	192	209	226	243	261	278	29$\bar{5}$
253	312	329	346	364	381	398	41$\bar{5}$	432	449	466
254	483	500	518	53$\bar{5}$	552	569	586	603	620	637
255	654	671	688	705	722	739	756	773	790	807
256	824	841	858	87$\bar{5}$	892	909	926	943	960	976
257	993	*010	*027	*044	*061	*078	*09$\bar{5}$	*111	*128	*145
258	41 162	179	196	212	229	246	263	280	296	313
259	330	347	363	380	397	414	430	447	464	481
260	497	514	531	547	564	581	597	614	631	647
261	664	681	697	714	731	747	764	780	797	814
262	830	847	863	880	896	913	929	946	963	979
263	996	*012	*029	*045	*062	*078	*09$\bar{5}$	*111	*127	*144
264	42 160	177	193	210	226	243	259	275	292	308
265	32$\bar{5}$	341	357	374	390	406	423	439	455	472
266	488	504	521	537	553	570	586	602	619	63$\bar{5}$
267	651	667	684	700	716	732	749	76$\bar{5}$	781	797
268	813	830	846	862	878	894	911	927	943	959
269	975	991	*008	*024	*040	*056	*072	*088	*104	*120
270	43 136	152	169	18$\bar{5}$	201	217	233	249	26$\bar{5}$	281
271	297	313	329	34$\bar{5}$	361	377	393	409	42$\bar{5}$	441
272	457	473	489	50$\bar{5}$	521	537	553	569	584	600
273	616	632	648	664	680	696	712	727	743	759
274	775	791	807	823	838	854	870	886	902	917
275	933	949	96$\bar{5}$	981	996	*012	*028	*044	*059	*075
276	44 091	107	122	138	154	170	185	201	217	232
277	248	264	279	29$\bar{5}$	311	326	342	358	373	389
278	404	420	436	451	467	483	498	514	529	54$\bar{5}$
279	560	576	592	607	623	638	654	669	68$\bar{5}$	700
280	716	731	747	762	778	793	809	824	840	855
281	871	886	902	917	932	948	963	979	994	*010
282	45 02$\bar{5}$	040	056	071	086	102	117	133	148	163
283	179	194	209	22$\bar{5}$	240	255	271	286	301	317
284	332	347	362	378	393	408	423	439	454	469
285	484	$\bar{5}$00	51$\bar{5}$	530	545	561	576	591	606	621
286	637	652	667	682	697	712	728	743	758	773
287	788	803	818	834	849	864	879	894	909	924
288	939	954	969	984	*000	*01$\bar{5}$	*030	*04$\bar{5}$	*060	*07$\bar{5}$
289	46 090	10$\bar{5}$	120	13$\bar{5}$	1$\bar{5}$0	16$\bar{5}$	180	19$\bar{5}$	210	22$\bar{5}$
290	240	25$\bar{5}$	270	28$\bar{5}$	300	31$\bar{5}$	330	34$\bar{5}$	359	374
291	389	404	419	434	449	464	479	494	509	523
292	538	553	568	583	598	613	627	642	657	672
293	687	702	716	731	746	761	776	790	805	820
294	83$\bar{5}$	8$\bar{5}$0	864	879	894	909	923	938	953	967
295	982	997	*012	*026	*041	*056	*070	*085	*100	*114
296	47 129	144	159	173	188	202	217	232	246	261
297	276	290	30$\bar{5}$	319	334	349	363	378	392	407
298	422	436	451	465	480	494	509	524	538	553
299	567	582	596	611	625	640	654	669	683	698
300	712	727	741	756	770	784	799	813	828	842
N.	L. 0	1	2	3	4	5	6	7	8	9

Prop. Parts

	18	**17**	**16**	**15**	**14**
1	1.8	1.7	1.6	1.5	1.4
2	3.6	3.4	3.2	3.0	2.8
3	5.4	5.1	4.8	4.5	4.2
4	7.2	6.8	6.4	6.0	5.6
5	9.0	8.5	8.0	7.5	7.0
6	10.8	10.2	9.6	9.0	8.4
7	12.6	11.9	11.2	10.5	9.8
8	14.4	13.6	12.8	12.0	11.2
9	16.2	15.3	14.4	13.5	12.6

log e = 0.43429

0° 4′ = 240″	S. 4.68 557	T. 4.68 558	
0 5 = 300	557	558	
0 41 = 2460	556	560	
0 42 = 2520	556	560	
0 43 = 2580	556	560	
0 44 = 2640	556	560	
0° 45′ = 2700″	S. 4.68 556	T 4.68 560	
0 46 = 2760	556	560	
0 47 = 2820	556	560	
0 48 = 2880	556	560	
0 49 = 2940	556	560	
0 50 = 3000	556	560	

N.	L. 0	1	2	3	4	5	6	7	8	9
200	30 103	12$\bar{5}$	146	168	190	211	233	25$\bar{5}$	276	298
201	320	341	363	384	406	428	449	471	492	514
202	535	557	578	600	621	643	664	685	707	728
203	7$\bar{5}$0	771	792	814	835	856	878	899	920	942
204	963	984	*006	*027	*048	*069	*091	*112	*133	*154
205	31 175	197	218	239	260	281	302	323	34$\bar{5}$	366
206	387	408	429	4$\bar{5}$0	471	492	513	534	555	576
207	597	618	639	660	681	702	723	744	76$\bar{5}$	785
208	806	827	848	869	890	911	931	952	973	994
209	32 01$\bar{5}$	035	056	077	098	118	139	160	181	201
210	222	243	263	284	30$\bar{5}$	325	346	366	387	408
211	428	449	469	490	510	531	552	572	593	613
212	634	654	67$\bar{5}$	69$\bar{5}$	715	736	756	777	797	818
213	838	858	879	899	919	940	960	980	*001	*021
214	33 041	062	082	102	122	143	163	183	203	224
215	244	264	284	304	32$\bar{5}$	34$\bar{5}$	36$\bar{5}$	385	405	425
216	445	465	486	506	526	546	566	586	606	626
217	646	666	686	706	726	746	766	786	806	826
218	846	866	885	905	925	945	965	98$\bar{5}$	*00$\bar{5}$	*02$\bar{5}$
219	34 044	064	084	104	124	143	163	183	203	223
220	242	262	282	301	321	341	361	380	400	420
221	439	459	479	498	518	537	557	577	596	616
222	635	65$\bar{5}$	674	694	713	733	753	772	792	811
223	830	8$\bar{5}$0	869	889	908	928	947	967	986	*005
224	35 02$\bar{5}$	044	064	083	102	122	141	160	180	199
225	218	238	257	276	295	31$\bar{5}$	334	353	372	392
226	411	430	449	468	488	507	526	545	564	583
227	603	622	641	660	679	698	717	736	755	774
228	793	813	832	851	870	889	908	927	946	96$\bar{5}$
229	984	*003	*021	*040	*059	*078	*097	*116	*135	*154
230	36 173	192	211	229	248	267	286	30$\bar{5}$	324	342
231	361	380	399	418	436	455	474	493	511	530
232	549	568	586	60$\bar{5}$	624	642	661	680	698	717
233	736	754	773	791	810	829	847	866	884	903
234	922	940	959	977	996	*014	*033	*051	*070	*088
235	37 107	125	144	162	181	199	218	236	254	273
236	291	310	328	346	36$\bar{5}$	383	401	420	438	457
237	47$\bar{5}$	493	511	530	548	566	58$\bar{5}$	603	621	639
238	658	676	694	712	731	749	767	785	803	822
239	840	858	876	894	912	931	949	967	98$\bar{5}$	*003
240	38 021	039	057	075	093	112	130	148	166	184
241	202	220	238	256	274	292	310	328	346	364
242	382	399	417	435	453	471	489	507	52$\bar{5}$	543
243	561	578	596	614	632	6$\bar{5}$0	668	686	703	721
244	739	757	77$\bar{5}$	792	810	828	846	863	881	899
245	917	934	952	970	987	*005	*023	*041	*058	*076
246	39 094	111	129	146	164	182	199	217	23$\bar{5}$	252
247	270	287	30$\bar{5}$	322	340	358	375	393	410	428
248	445	463	480	498	515	533	550	568	585	602
249	620	637	65$\bar{5}$	672	690	707	724	742	759	777
250	794	811	829	846	863	881	898	915	933	950
N.	L. 0	1	2	3	4	5	6	7	8	9

Prop. Parts

	22	21
1	2.2	2.1
2	4.4	4.2
3	6.6	6.3
4	8.8	8.4
5	11.0	10.5
6	13.2	12.6
7	15.4	14.7
8	17.6	16.8
9	19.8	18.9

	20	19	18	17
1	2.0	1.9	1.8	1.7
2	4.0	3.8	3.6	3.4
3	6.0	5.7	5.4	5.1
4	8.0	7.6	7.2	6.8
5	10.0	9.5	9.0	8.5
6	12.0	11.4	10.8	10.2
7	14.0	13.3	12.6	11.9
8	16.0	15.2	14.4	13.6
9	18.0	17.1	16.2	15.3

		S.	T.
0° 3′	= 180″	4.68 557	4.68 557
0 4	= 240	557	558
0 5	= 300	557	558
0 33	=1980	557	559
0 34	=2040	557	559
0 35	=2100	557	559

		S.	T.
0° 36′	=2160″	4.68 557	4.68 559
0 37	=2220	557	559
0 38	=2280	557	559
0 39	=2340	557	559
0 40	=2400	557	559
0 41	=2460	556	560
0 42	=2520	556	560

N.	L. 0	1	2	3	4	5	6	7	8	9
250	39 794	811	829	846	863	881	898	915	933	950
251	967	985̄	*002	*019	*037	*054	*071	*088	*106	*123
252	40 140	157	175̄	192	209	226	243	261	278	295̄
253	312	329	346	364	381	398	415̄	432	449	466
254	483	500	518	535̄	552	569	586	603	620	637
255	654	671	688	705	722	739	756	773	790	807
256	824	841	858	875̄	892	909	926	943	960	976
257	993	*010	*027	*044	*061	*078	*095̄	*111	*128	*145
258	41 162	179	196	212	229	246	263	280	296	313
259	330	347	363	380	397	414	430	447	464	481
260	497	514	531	547	564	581	597	614	631	647
261	664	681	697	714	731	747	764	780	797	814
262	830	847	863	880	896	913	929	946	963	979
263	996	*012	*029	*045	*062	*078	*095̄	*111	*127	*144
264	42 160	177	193	210	226	243	259	275	292	308
265	325̄	341	357	374	390	406	423	439	455	472
266	488	504	521	537	553	570	586	602	619	635̄
267	651	667	684	700	716	732	749	765̄	781	797
268	813	830	846	862	878	894	911	927	943	959
269	975	991	*008	*024	*040	*056	*072	*088	*104	*120
270	43 136	152	169	185̄	201	217	233	249	265̄	281
271	297	313	329	345̄	361	377	393	409	425̄	441
272	457	473	489	505̄	521	537	553	569	584	600
273	616	632	648	664	680	696	712	727	743	759
274	775	791	807	823	838	854	870	886	902	917
275	933	949	965̄	981	996	*012	*028	*044	*059	*075
276	44 091	107	122	138	154	170	185	201	217	232
277	248	264	279	295̄	311	326	342	358	373	389
278	404	420	436	451	467	483	498	514	529	545̄
279	560	576	592	607	623	638	654	669	685̄	700
280	716	731	747	762	778	793	809	824	840	855
281	871	886	902	917	932	948	963	979	994	*010
282	45 025̄	040	056	071	086	102	117	133	148	163
283	179	194	209	225̄	240	255	271	286	301	317
284	332	347	362	378	393	408	423	439	454	469
285	484	5̄00	515̄	530	545	561	576	591	606	621
286	637	652	667	682	697	712	728	743	758	773
287	788	803	818	834	849	864	879	894	909	924
288	939	954	969	984	*000	*015̄	*030	*045̄	*060	*075̄
289	46 090	105̄	120	135̄	1̄50	165̄	180	195̄	210	225̄
290	240	255̄	270	285̄	300	315̄	330	345̄	359	374
291	389	404	419	434	449	464	479	494	509	523
292	538	553	568	583	598	613	627	642	657	672
293	687	702	716	731	746	761	776	790	805	820
294	835̄	8̄50	864	879	894	909	923	938	953	967
295	982	997	*012	*026	*041	*056	*070	*085	*100	*114
296	47 129	144	159	173	188	202	217	232	246	261
297	276	290	305̄	319	334	349	363	378	392	407
298	422	436	451	465	480	494	509	524	538	553
299	567	582	596	611	625	640	654	669	683	698
300	712	727	741	756	770	784	799	813	828	842
N.	L. 0	1	2	3	4	5	6	7	8	9

Prop. Parts

	18	**17**	**16**	**15**	**14**
1	1.8	1.7	1.6	1.5	1.4
2	3.6	3.4	3.2	3.0	2.8
3	5.4	5.1	4.8	4.5	4.2
4	7.2	6.8	6.4	6.0	5.6
5	9.0	8.5	8.0	7.5	7.0
6	10.8	10.2	9.6	9.0	8.4
7	12.6	11.9	11.2	10.5	9.8
8	14.4	13.6	12.8	12.0	11.2
9	16.2	15.3	14.4	13.5	12.6

log e = 0.43429

0° 4′ = 240″	S. 4.68 557	T. 4.68 558	
0 5 = 300	557	558	
0 41 = 2460	556	560	
0 42 = 2520	556	560	
0 43 = 2580	556	560	
0 44 = 2640	556	560	
0° 45′ = 2700″	S. 4.68 556	T 4.68 560	
0 46 = 2760	556	560	
0 47 = 2820	556	560	
0 48 = 2880	556	560	
0 49 = 2940	556	560	
0 50 = 3000	556	560	

N.	L. 0	1	2	3	4	5	6	7	8	9
300	47 712	727	741	756	770	784	799	813	828	842
301	857	871	885	900	914	929	943	958	972	986
302	48 001	015	029	044	058	073	087	101	116	130
303	144	159	173	187	202	216	230	244	259	273
304	287	302	316	330	344	359	373	387	401	416
305	430	444	458	473	487	501	515	530	544	558
306	572	586	601	615	629	643	657	671	686	700
307	714	728	742	756	770	785	799	813	827	841
308	855	869	883	897	911	926	940	954	968	982
309	996	*010	*024	*038	*052	*066	*080	*094	*108	*122
310	49 136	150	164	178	192	206	220	234	248	262
311	276	290	304	318	332	346	360	374	388	402
312	415	429	443	457	471	485	499	513	527	541
313	554	568	582	596	610	624	638	651	665	679
314	693	707	721	734	748	762	776	790	803	817
315	831	845	859	872	886	900	914	927	941	955
316	969	982	996	*010	*024	*037	*051	*065	*079	*092
317	50 106	120	133	147	161	174	188	202	215	229
318	243	256	270	284	297	311	325	338	352	365
319	379	393	406	420	433	447	461	474	488	501
320	515	529	542	556	569	583	596	610	623	637
321	651	664	678	691	705	718	732	745	759	772
322	786	799	813	826	840	853	866	880	893	907
323	920	934	947	961	974	987	*001	*014	*028	*041
324	51 055	068	081	095	108	121	135	148	162	175
325	188	202	215	228	242	255	268	282	295	308
326	322	335	348	362	375	388	402	415	428	441
327	455	468	481	495	508	521	534	548	561	574
328	587	601	614	627	640	654	667	680	693	706
329	720	733	746	759	772	786	799	812	825	838
330	851	865	878	891	904	917	930	943	957	970
331	983	996	*009	*022	*035	*048	*061	*075	*088	*101
332	52 114	127	140	153	166	179	192	205	218	231
333	244	257	270	284	297	310	323	336	349	362
334	375	388	401	414	427	440	453	466	479	492
335	504	517	530	543	556	569	582	595	608	621
336	634	647	660	673	686	699	711	724	737	750
337	763	776	789	802	815	827	840	853	866	879
338	892	905	917	930	943	956	969	982	994	*007
339	53 020	033	046	058	071	084	097	110	122	135
340	148	161	173	186	199	212	224	237	250	263
341	275	288	301	314	326	339	352	364	377	390
342	403	415	428	441	453	466	479	491	504	517
343	529	542	555	567	580	593	605	618	631	643
344	656	668	681	694	706	719	732	744	757	769
345	782	794	807	820	832	845	857	870	882	895
346	908	920	933	945	958	970	983	995	*008	*020
347	54 033	045	058	070	083	095	108	120	133	145
348	158	170	183	195	208	220	233	245	258	270
349	283	295	307	320	332	345	357	370	382	394
350	407	419	432	444	456	469	481	494	506	518

N. | L. 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Prop. Parts

Prop. Parts

	15	14	13	12
1	1.5	1.4	1.3	1.2
2	3.0	2.8	2.6	2.4
3	4.5	4.2	3.9	3.6
4	6.0	5.6	5.2	4.8
5	7.5	7.0	6.5	6.0
6	9.0	8.4	7.8	7.2
7	10.5	9.8	9.1	8.4
8	12.0	11.2	10.4	9.6
9	13.5	12.6	11.7	10.8

$\log \pi = 0.49715$

		S.	T.
0° 5′	= 300″	4.68 557	4.68 558
0 6	= 360	557	558
0 50	=3000	556	561
0 51	=3060	556	561
0 52	=3120	556	561
0 53	=3180	556	561
0° 54′	=3240″	4.68 556	4.68 561
0 55	=3300	556	561
0 56	=3360	556	561
0 57	=3420	555	561
0 58	=3480	555	562
0 59	=3540	555	562

350-400

N.	L. 0	1	2	3	4	5	6	7	8	9
350	54 407	419	432	444	456	469	481	494	506	518
351	531	543	555	568	580	593	605	617	630	642
352	654	667	679	691	704	716	728	741	753	765
353	777	790	802	814	827	839	851	864	876	888
354	900	913	925	937	949	962	974	986	998	*011
355	55 023	035	047	060	072	084	096	108	121	133
356	145	157	169	182	194	206	218	230	242	255
357	267	279	291	303	315	328	340	352	364	376
358	388	400	413	425	437	449	461	473	485	497
359	509	522	534	546	558	570	582	594	606	618
360	630	642	654	666	678	691	703	715	727	739
361	751	763	775	787	799	811	823	835	847	859
362	871	883	895	907	919	931	943	955	967	979
363	991	*003	*015	*027	*038	*050	*062	*074	*086	*098
364	56 110	122	134	146	158	170	182	194	205	217
365	229	241	253	265	277	289	301	312	324	336
366	348	360	372	384	396	407	419	431	443	455
367	467	478	490	502	514	526	538	549	561	573
368	585	597	608	620	632	644	656	667	679	691
369	703	714	726	738	750	761	773	785	797	808
370	820	832	844	855	867	879	891	902	914	926
371	937	949	961	972	984	996	*008	*019	*031	*043
372	57 054	066	078	089	101	113	124	136	148	159
373	171	183	194	206	217	229	241	252	264	276
374	287	299	310	322	334	345	357	368	380	392
375	403	415	426	438	449	461	473	484	496	507
376	519	530	542	553	565	576	588	600	611	623
377	634	646	657	669	680	692	703	715	726	738
378	749	761	772	784	795	807	818	830	841	852
379	864	875	887	898	910	921	933	944	955	967
380	978	990	*001	*013	*024	*035	*047	*058	*070	*081
381	58 092	104	115	127	138	149	161	172	184	195
382	206	218	229	240	252	263	274	286	297	309
383	320	331	343	354	365	377	388	399	410	422
384	433	444	456	467	478	490	501	512	524	535
385	546	557	569	580	591	602	614	625	636	647
386	659	670	681	692	704	715	726	737	749	760
387	771	782	794	805	816	827	838	850	861	872
388	883	894	906	917	928	939	950	961	973	984
389	995	*006	*017	*028	*040	*051	*062	*073	*084	*095
390	59 106	118	129	140	151	162	173	184	195	207
391	218	229	240	251	262	273	284	295	306	318
392	329	340	351	362	373	384	395	406	417	428
393	439	450	461	472	483	494	506	517	528	539
394	550	561	572	583	594	605	616	627	638	649
395	660	671	682	693	704	715	726	737	748	759
396	770	780	791	802	813	824	835	846	857	868
397	879	890	901	912	923	934	945	956	966	977
398	988	999	*010	*021	*032	*043	*054	*065	*076	*086
399	60 097	108	119	130	141	152	163	173	184	195
400	206	217	228	239	249	260	271	282	293	304
N.	L. 0	1	2	3	4	5	6	7	8	9

Prop. Parts

	13	12	11	10
1	1.3	1.2	1.1	1.0
2	2.6	2.4	2.2	2.0
3	3.9	3.6	3.3	3.0
4	5.2	4.8	4.4	4.0
5	6.5	6.0	5.5	5.0
6	7.8	7.2	6.6	6.0
7	9.1	8.4	7.7	7.0
8	10.4	9.6	8.8	8.0
9	11.7	10.8	9.9	9.0

		S.	T.
0° 5′	= 300″	S. 4.68 557	T. 4.68 558
0 6	= 360	557	558
0 7	= 420	557	558
0 58	= 3480	555	562
0 59	= 3540	555	562
1 0	= 3600	555	562

		S.	T.
1° 1′	= 3660″	S. 4.68 555	T. 4.68 562
1 2	= 3720	555	562
1 3	= 3780	555	562
1 4	= 3840	555	563
1 5	= 3900	555	563
1 6	= 3960	555	563
1 7	= 4020	555	563

400-450

N.	L. 0	1	2	3	4	5	6	7	8	9
400	60 206	217	228	239	249	260	271	282	293	304
401	314	325	336	347	358	369	379	390	401	412
402	423	433	444	455	466	477	487	498	509	520
403	531	541	552	563	574	584	595	606	617	627
404	638	649	660	670	681	692	703	713	724	73$\bar{5}$
405	746	756	767	778	788	799	810	821	831	842
406	853	863	874	88$\bar{5}$	895	906	917	927	938	949
407	959	970	981	991	*002	*013	*023	*034	*04$\bar{5}$	*055
408	61 066	077	087	098	109	119	130	140	151	162
409	172	183	194	204	21$\bar{5}$	225	236	247	257	268
410	278	289	300	310	321	331	342	352	363	374
411	384	39$\bar{5}$	405	416	426	437	448	458	469	479
412	490	500	511	521	532	542	553	563	574	584
413	595	606	616	627	637	648	658	669	679	690
414	700	711	721	731	742	752	763	773	784	794
415	80$\bar{5}$	815	826	836	847	857	868	878	888	899
416	909	920	930	941	951	962	972	982	993	*003
417	62 014	024	034	04$\bar{5}$	055	066	076	086	097	107
418	118	128	138	149	159	170	180	190	201	211
419	221	232	242	252	263	273	284	294	304	31$\bar{5}$
420	32$\bar{5}$	335	346	356	366	377	387	397	408	418
421	428	439	449	459	469	480	490	500	511	521
422	531	542	552	562	572	583	593	603	613	624
423	634	644	65$\bar{5}$	66$\bar{5}$	675	685	696	706	716	726
424	737	747	757	767	778	788	798	808	818	829
425	839	849	859	870	880	890	900	910	921	931
426	941	951	961	972	982	992	*002	*012	*022	*033
427	63 043	053	063	073	083	094	104	114	124	134
428	144	15$\bar{5}$	16$\bar{5}$	17$\bar{5}$	18$\bar{5}$	195	205	215	225	236
429	246	256	266	276	286	296	306	317	327	337
430	347	357	367	377	387	397	407	417	428	438
431	448	458	468	478	488	498	508	518	528	538
432	548	558	568	579	589	599	609	619	629	639
433	649	659	669	679	689	699	709	719	729	739
434	749	759	769	779	789	799	809	819	829	839
435	849	859	869	879	889	899	909	919	929	939
436	949	959	969	979	988	998	*008	*018	*028	*038
437	64 048	058	068	078	088	098	108	118	128	137
438	147	157	167	177	187	197	207	217	227	237
439	246	256	266	276	286	296	306	316	326	335
440	345	355	365	37$\bar{5}$	38$\bar{5}$	39$\bar{5}$	404	414	424	434
441	444	454	464	473	483	493	503	513	523	532
442	542	552	562	572	582	591	601	611	621	631
443	640	650	660	670	680	689	699	709	719	729
444	738	748	758	768	777	787	797	807	816	826
445	836	846	856	865	875	88$\bar{5}$	89$\bar{5}$	904	914	924
446	933	943	953	963	972	982	992	*002	*011	*021
447	65 031	040	050	060	070	079	089	099	108	118
448	128	137	147	157	167	176	186	196	205	21$\bar{5}$
449	22$\bar{5}$	234	244	254	263	273	283	292	302	312
450	321	331	341	350	360	369	379	389	398	408
N.	L. 0	1	2	3	4	5	6	7	8	9

Prop. Parts

	11	10	9
1	1.1	1.0	0.9
2	2.2	2.0	1.8
3	3.3	3.0	2.7
4	4.4	4.0	3.6
5	5.5	5.0	4.5
6	6.6	6.0	5.4
7	7.7	7.0	6.3
8	8.8	8.0	7.2
9	9.9	9.0	8.1

		S.	T.
0° 6′	= 360″	4.68 557	4.68 558
0 7	= 420	557	558
0 8	= 480	557	558
1 6	= 3960	55$\bar{5}$	563
1 7	= 4020	55$\bar{5}$	563
1 8	= 4080	55$\bar{5}$	563
1° 9′	= 4140″	4.68 55$\bar{5}$	4.68 563
1 10	= 4200	554	563
1 11	= 4260	554	564
1 12	= 4320	554	564
1 13	= 4380	554	564
1 14	= 4440	554	564
1 15	= 4500	554	564

450-500

N.	L. 0	1	2	3	4	5	6	7	8	9
450	65 321	331	341	350	360	369	379	389	398	408
451	418	427	437	447	456	466	475	485	495̄	504
452	514	523	533	543	552	562	571	581	591	600
453	610	619	629	639	648	658	667	677	686	696
454	706	715	725̄	734	744	753	763	772	782	792
455	801	811	820	830	839	849	858	868	877	887
456	896	906	916	925	935̄	944	954	963	973	982
457	992	*001	*011	*020	*030	*039	*049	*058	*068	*077
458	66 087	096	106	115̄	124	134	143	153	162	172
459	181	191	200	210	219	229	238	247	257	266
460	276	285	295̄	304	314	323	332	342	351	361
461	370	380	389	398	408	417	427	436	445	455̄
462	464	474	483	492	502	511	521	530	539	549
463	558	567	577	586	596	605̄	614	624	633	642
464	652	661	671	680	689	699	708	717	727	736
465	745	755̄	764	773	783	792	801	811	820	829
466	839	848	857	867	876	885	894	904	913	922
467	932	941	950	960	969	978	987	997	*006	*015
468	67 025̄	034	043	052	062	071	080	089	099	108
469	117	127	136	145	154	164	173	182	191	201
470	210	219	228	237	247	256	265	274	284	293
471	302	311	321	330	339	348	357	367	376	385̄
472	394	403	413	422	431	440	449	459	468	477
473	486	495	504	514	523	532	541	550	560	569
474	578	587	596	605	614	624	633	642	651	660
475	669	679	688	697	706	715	724	733	742	752
476	761	770	779	788	797	806	815	825̄	834	843
477	852	861	870	879	888	897	906	916	925̄	934
478	943	952	961	970	979	988	997	*006	*015	*024
479	68 034	043	052	061	070	079	088	097	106	115
480	124	133	142	151	160	169	178	187	196	205
481	215̄	224	233	242	251	260	269	278	287	296
482	305̄	314	323	332	341	35̄0	359	368	377	386
483	395̄	404	413	422	431	440	449	458	467	476
484	485̄	494	502	511	520	529	538	547	556	565
485	574	583	592	601	610	619	628	637	646	655̄
486	664	673	681	690	699	708	717	726	735	744
487	753	762	771	780	789	797	806	815	824	833
488	842	851	860	869	878	886	895	904	913	922
489	931	940	949	958	966	975	984	993	*002	*011
490	69 020	028	037	046	055	064	073	082	090	099
491	108	117	126	135̄	144	152	161	170	179	188
492	197	205	214	223	232	241	249	258	267	276
493	285̄	294	302	311	320	329	338	346	355	364
494	373	381	390	399	408	417	425	434	443	452
495	461	469	478	487	496	504	513	522	531	539
496	548	557	566	574	583	592	601	609	618	627
497	636	644	653	662	671	679	688	697	705	714
498	723	732	740	749	758	767	775	784	793	801
499	810	819	827	836	845̄	854	862	871	880	888
500	897	906	914	923	932	940	949	958	966	975
N.	L. 0	1	2	3	4	5	6	7	8	9

Prop. Parts

	10	9	8
1	1.0	0.9	0.8
2	2.0	1.8	1.6
3	3.0	2.7	2.4
4	4.0	3.6	3.2
5	5.0	4.5	4.0
6	6.0	5.4	4.8
7	7.0	6.3	5.6
8	8.0	7.2	6.4
9	9.0	8.1	7.2

		S.	T.
0° 7′	= 420″	4.68 557	4.68 558
0 8	= 480	557	558
0 9	= 540	557	558
1 15	= 4500	554	564
1 16	= 4560	554	565̄
1 17	= 4620	554	565̄
1° 18′	= 4680″	4.68 554	4.68 565̄
1 19	= 4740	554	565
1 20	= 4800	554	565
1 21	= 4860	553	566
1 22	= 4920	553	566
1 23	= 4980	553	566
1 24	= 5040	553	566

500-550

N.	L. 0	1	2	3	4	5	6	7	8	9
500	69 897	906	914	923	932	940	949	958	966	975
501	984	992	*001	*010	*018	*027	*036	*044	*053	*062
502	70 070	079	088	096	105̄	114	122	131	140	148
503	157	165	174	183	191	200	209	217	226	234
504	243	252	260	269	278	286	295̄	303	312	321
505	329	338	346	355̄	364	372	381	389	398	406
506	415	424	432	441	449	458	467	475	484	492
507	501	509	518	526	535	544	552	561	569	578
508	586	595̄	603	612	621	629	638	646	655̄	663
509	672	680	689	697	706	714	723	731	740	749
510	757	766	774	783	791	800	808	817	825	834
511	842	851	859	868	876	885̄	893	902	910	919
512	927	935	944	952	961	969	978	986	995̄	*003
513	71 012	020	029	037	046	054	063	071	079	088
514	096	105̄	113	122	130	139	147	155	164	172
515	181	189	198	206	214	223	231	240	248	257
516	265̄	273	282	290	299	307	315	324	332	341
517	349	357	366	374	383	391	399	408	416	425̄
518	433	441	450	458	466	475̄	483	492	500	508
519	517	525	533	542	550	559	567	575	584	592
520	600	609	617	625	634	642	650	659	667	675
521	684	692	700	709	717	725	734	742	750	759
522	767	775	784	792	800	809	817	825	834	842
523	850	858	867	875	883	892	900	908	917	925̄
524	933	941	950	958	966	975̄	983	991	999	*008
525	72 016	024	032	041	049	057	066	074	082	090
526	099	107	115	123	132	140	148	156	165̄	173
527	181	189	198	206	214	222	230	239	247	255
528	263	272	280	288	296	304	313	321	329	337
529	346	354	362	370	378	387	395̄	403	411	419
530	428	436	444	452	460	469	477	485̄	493	501
531	509	518	526	534	542	550	558	567	575̄	583
532	591	599	607	616	624	632	640	648	656	665̄
533	673	681	689	697	705	713	722	730	738	746
534	754	762	770	779	787	795̄	803	811	819	827
535	835	843	852	860	868	876	884	892	900	908
536	916	925̄	933	941	949	957	965	973	981	989
537	997	*006	*014	*022	*030	*038	*046	*054	*062	*070
538	73 078	086	094	102	111	119	127	135̄	143	151
539	159	167	175̄	183	191	199	207	215	223	231
540	239	247	255	263	272	280	288	296	304	312
541	320	328	336	344	352	360	368	376	384	392
542	400	408	416	424	432	440	448	456	464	472
543	480	488	496	504	512	520	528	536	544	552
544	560	568	576	584	592	600	608	616	624	632
545	640	648	656	664	672	679	687	695	703	711
546	719	727	735	743	751	759	767	775̄	783	791
547	799	807	815̄	823	830	838	846	854	862	870
548	878	886	894	902	910	918	926	933	941	949
549	957	965	973	981	989	997	*005̄	*013	*020	*028
550	74 036	044	052	060	068	076	084	092	099	107
N.	L. 0	1	2	3	4	5	6	7	8	9

Prop. Parts

	9
1	0.9
2	1.8
3	2.7
4	3.6
5	4.5
6	5.4
7	6.3
8	7.2
9	8.1

	8
1	0.8
2	1.6
3	2.4
4	3.2
5	4.0
6	4.8
7	5.6
8	6.4
9	7.2

	7
1	0.7
2	1.4
3	2.1
4	2.8
5	3.5
6	4.2
7	4.9
8	5.6
9	6.3

		S.	T.
0° 8′	= 480″	S. 4.68 557	T. 4.68 558
0 9	= 540	557	558
0 10	= 600	557	558
1 23	= 4980	553	566
1 24	= 5040	553	566
1 25	= 5100	553	566

		S.	T.
1° 26′	= 5160″	S. 4.68 553	T. 4.68 567
1 27	= 5220	553	567
1 28	= 5280	553	567
1 29	= 5340	553	567
1 30	= 5400	553	567
1 31	= 5460	552	568
1 32	= 5520	552	568

N.	L. 0	1	2	3	4	5	6	7	8	9	Prop. Parts	
550	74 036	044	052	060	068	076	084	092	099	107		
551	115	123	131	139	147	155	162	170	178	186		
552	194	202	210	218	225	233	241	249	257	265		
553	273	280	288	296	304	312	320	327	335	343		
554	351	359	367	374	382	390	398	406	414	421		
555	429	437	445	453	461	468	476	484	492	500		
556	507	515	523	531	539	547	554	562	570	578		
557	586	593	601	609	617	624	632	640	648	656		
558	663	671	679	687	695	702	710	718	726	733		
559	741	749	757	764	772	780	788	796	803	811		
560	819	827	834	842	850	858	865	873	881	889		8
561	896	904	912	920	927	935	943	950	958	966	1	0.8
562	974	981	989	997	*005	*012	*020	*028	*035	*043	2	1.6
563	75 051	059	066	074	082	089	097	105	113	120	3	2.4
564	128	136	143	151	159	166	174	182	189	197	4	3.2
565	205	213	220	228	236	243	251	259	266	274	5	4.0
566	282	289	297	305	312	320	328	335	343	351	6	4.8
567	358	366	374	381	389	397	404	412	420	427	7	5.6
568	435	442	450	458	465	473	481	488	496	504	8	6.4
569	511	519	526	534	542	549	557	565	572	580	9	7.2
570	587	595	603	610	618	626	633	641	648	656		
571	664	671	679	686	694	702	709	717	724	732		
572	740	747	755	762	770	778	785	793	800	808		
573	815	823	831	838	846	853	861	868	876	884		
574	891	899	906	914	921	929	937	944	952	959		
575	967	974	982	989	997	*005	*012	*020	*027	*035		
576	76 042	050	057	065	072	080	087	095	103	110		
577	118	125	133	140	148	155	163	170	178	185		
578	193	200	208	215	223	230	238	245	253	260		
579	268	275	283	290	298	305	313	320	328	335		
580	343	350	358	365	373	380	388	395	403	410		7
581	418	425	433	440	448	455	462	470	477	485	1	0.7
582	492	500	507	515	522	530	537	545	552	559	2	1.4
583	567	574	582	589	597	604	612	619	626	634	3	2.1
584	641	649	656	664	671	678	686	693	701	708	4	2.8
585	716	723	730	738	745	753	760	768	775	782	5	3.5
586	790	797	805	812	819	827	834	842	849	856	6	4.2
587	864	871	879	886	893	901	908	916	923	930	7	4.9
588	938	945	953	960	967	975	982	989	997	*004	8	5.6
589	77 012	019	026	034	041	048	056	063	070	078	9	6.3
590	085	093	100	107	115	122	129	137	144	151		
591	159	166	173	181	188	195	203	210	217	225		
592	232	240	247	254	262	269	276	283	291	298		
593	305	313	320	327	335	342	349	357	364	371		
594	379	386	393	401	408	415	422	430	437	444		
595	452	459	466	474	481	488	495	503	510	517		
596	525	532	539	546	554	561	568	576	583	590		
597	597	605	612	619	627	634	641	648	656	663		
598	670	677	685	692	699	706	714	721	728	735		
599	743	750	757	764	772	779	786	793	801	808		
600	815	822	830	837	844	851	859	866	873	880		

N. L. 0 1 2 3 4 5 6 7 8 9 Prop. Parts

0° 9′ = 540″	S. 4.68 557	T. 4.68 558	
0 10 = 600	557	558	
1 31 = 5460	552	568	
1 32 = 5520	552	568	
1 33 = 5580	552	568	
1 34 = 5640	552	568	
1° 35′ = 5700″	S. 4.68 552	T. 4.68 569	
1 36 = 5760	552	569	
1 37 = 5820	552	569	
1 38 = 5880	552	569	
1 39 = 5940	551	569	
1 40 = 6000	551	570	

N.	L. 0	1	2	3	4	5	6	7	8	9
600	77 815	822	830	837	844	851	859	866	873	880
601	887	89$\bar{5}$	902	909	916	924	931	938	945	952
602	960	967	974	981	988	996	*003	*010	*017	*02$\bar{5}$
603	78 032	039	046	053	061	068	07$\bar{5}$	082	089	097
604	104	111	118	125	132	140	147	154	161	168
605	176	183	190	197	204	211	219	226	233	240
606	247	254	262	269	276	283	290	297	30$\bar{5}$	312
607	319	326	333	340	347	35$\bar{5}$	362	369	376	383
608	390	398	40$\bar{5}$	412	419	426	433	440	447	45$\bar{5}$
609	462	469	476	483	490	497	504	512	519	526
610	533	540	547	554	561	569	576	583	590	597
611	604	611	618	625	633	640	647	654	661	668
612	675	682	689	696	704	711	718	72$\bar{5}$	732	739
613	746	753	760	767	774	781	789	796	803	810
614	817	824	831	838	845	852	859	866	873	880
615	888	89$\bar{5}$	902	909	916	923	930	937	944	951
616	958	965	972	979	986	993	*000	*007	*014	*021
617	79 029	036	043	0$\bar{5}$0	057	064	071	078	08$\bar{5}$	092
618	099	106	113	120	127	134	141	148	155	162
619	169	176	183	190	197	204	211	218	225	232
620	239	246	253	260	267	274	281	288	295	302
621	309	316	323	330	337	344	351	358	365	372
622	379	386	393	400	407	414	421	428	43$\bar{5}$	442
623	449	456	463	470	477	484	491	498	50$\bar{5}$	511
624	518	525	532	539	546	553	560	567	574	581
625	588	59$\bar{5}$	602	609	616	623	630	637	644	650
626	657	664	671	678	685	692	699	706	713	720
627	727	734	741	748	754	761	768	775	782	789
628	796	803	810	817	824	831	837	844	851	858
629	865	872	879	886	893	900	906	913	920	927
630	934	941	948	95$\bar{5}$	962	969	975	982	989	996
631	80 003	010	017	024	030	037	044	051	058	06$\bar{5}$
632	072	079	085	092	099	106	113	120	127	134
633	140	147	154	161	168	17$\bar{5}$	182	188	195	202
634	209	216	223	229	236	243	250	257	264	271
635	277	284	291	298	30$\bar{5}$	312	318	325	332	339
636	346	353	359	366	373	380	387	393	400	407
637	414	421	428	434	441	448	45$\bar{5}$	462	468	475
638	482	489	496	502	509	516	523	530	536	543
639	550	557	564	570	577	584	591	598	604	611
640	618	62$\bar{5}$	632	638	645	652	659	665	672	679
641	686	693	699	706	713	720	726	733	740	747
642	754	760	767	774	781	787	794	801	808	814
643	821	828	83$\bar{5}$	841	848	85$\bar{5}$	862	868	875	882
644	889	895	902	909	916	922	929	936	943	949
645	956	963	969	976	983	990	996	*003	*010	*017
646	81 023	030	037	043	050	057	064	070	077	084
647	090	097	104	111	117	124	131	137	144	151
648	158	164	171	178	184	191	198	204	211	218
649	224	231	238	24$\bar{5}$	251	258	26$\bar{5}$	271	278	28$\bar{5}$
650	291	298	30$\bar{5}$	311	318	32$\bar{5}$	331	338	34$\bar{5}$	351
N.	L. 0	1	2	3	4	5	6	7	8	9

Prop. Parts

	8
1	0.8
2	1.6
3	2.4
4	3.2
5	4.0
6	4.8
7	5.6
8	6.4
9	7.2

	7
1	0.7
2	1.4
3	2.1
4	2.8
5	3.5
6	4.2
7	4.9
8	5.6
9	6.3

	6
1	0.6
2	1.2
3	1.8
4	2.4
5	3.0
6	3.6
7	4.2
8	4.8
9	5.4

0° 10′ = 600″	S. 4.68 557	T. 4.68 558
0 11 = 660	557	558
1 40 = 6000	551	570
1 41 = 6060	551	570
1 42 = 6120	551	570
1 43 = 6180	551	570
1° 44′ = 6240″	S. 4.68 551	T. 4.68 571
1 45 = 6300	551	571
1 46 = 6360	551	571
1 47 = 6420	550	572
1 48 = 6480	550	572
1 49 = 6540	550	572

650-700

N.	L. 0	1	2	3	4	5	6	7	8	9	Prop. Parts
650	81 291	298	30$\bar{5}$	311	318	32$\bar{5}$	331	338	34$\bar{5}$	351	
651	358	36$\bar{5}$	371	378	38$\bar{5}$	391	398	40$\bar{5}$	411	418	
652	42$\bar{5}$	431	438	44$\bar{5}$	451	458	46$\bar{5}$	471	478	48$\bar{5}$	
653	491	498	50$\bar{5}$	511	518	52$\bar{5}$	531	538	544	551	
654	558	564	571	578	584	591	598	604	611	617	
655	624	631	637	644	651	657	664	671	677	684	
656	690	697	704	710	717	723	730	737	743	7$\bar{5}$0	
657	757	763	770	776	783	790	796	803	809	816	
658	823	829	836	842	849	856	862	869	875	882	
659	889	895	902	908	91$\bar{5}$	921	928	93$\bar{5}$	941	948	
660	954	961	968	974	981	987	994	*000	*007	*014	
661	82 020	027	033	040	046	053	060	066	073	079	7
662	086	092	099	105	112	119	125	132	138	14$\bar{5}$	1 | 0.7
663	151	158	164	171	178	184	191	197	204	210	2 | 1.4
664	217	223	230	236	243	249	256	263	269	276	3 | 2.1
665	282	289	295	302	308	31$\bar{5}$	321	328	334	341	4 | 2.8
666	347	354	360	367	373	380	387	393	400	406	5 | 3.5
667	413	419	426	432	439	445	452	458	46$\bar{5}$	471	6 | 4.2
668	478	484	491	497	504	510	517	523	530	536	7 | 4.9
669	543	549	556	562	569	575	582	588	59$\bar{5}$	601	8 | 5.6
670	607	614	620	627	633	640	646	653	659	666	9 | 6.3
671	672	679	685	692	698	70$\bar{5}$	711	718	724	730	
672	737	743	7$\bar{5}$0	756	763	769	776	782	789	795	
673	802	808	814	821	827	834	840	847	853	860	
674	866	872	879	885	892	898	90$\bar{5}$	911	918	924	
675	930	937	943	9$\bar{5}$0	956	963	969	975	982	988	
676	99$\bar{5}$	*001	*008	*014	*020	*027	*033	*040	*046	*052	
677	83 059	065	072	078	08$\bar{5}$	091	097	104	110	117	
678	123	129	136	142	149	15$\bar{5}$	161	168	174	181	
679	187	193	200	206	213	219	225	232	238	24$\bar{5}$	
680	251	257	264	270	276	283	289	296	302	308	
681	31$\bar{5}$	321	327	334	340	347	353	359	366	372	6
682	378	38$\bar{5}$	391	398	404	410	417	423	429	436	1 | 0.6
683	442	448	45$\bar{5}$	461	467	474	480	487	493	499	2 | 1.2
684	506	512	518	52$\bar{5}$	531	537	544	550	556	563	3 | 1.8
685	569	575	582	588	594	601	607	613	620	626	4 | 2.4
686	632	639	645	651	658	664	670	677	683	689	5 | 3.0
687	696	702	708	71$\bar{5}$	721	727	734	740	746	753	6 | 3.6
688	759	765	771	778	784	790	797	803	809	816	7 | 4.2
689	822	828	83$\bar{5}$	841	847	853	860	866	872	879	8 | 4.8
690	88$\bar{5}$	891	897	904	910	916	923	929	935	942	9 | 5.4
691	948	954	960	967	973	979	985	992	998	*004	
692	84 011	017	023	029	036	042	048	05$\bar{5}$	061	067	
693	073	080	086	092	098	10$\bar{5}$	111	117	123	130	
694	136	142	148	15$\bar{5}$	161	167	173	180	186	192	
695	198	20$\bar{5}$	211	217	223	230	236	242	248	25$\bar{5}$	
696	261	267	273	280	286	292	298	30$\bar{5}$	311	317	
697	323	330	336	342	348	354	361	367	373	379	
698	386	392	398	404	410	417	423	429	435	442	
699	448	454	460	466	473	479	48$\bar{5}$	491	497	504	
700	510	516	522	528	53$\bar{5}$	541	547	553	559	566	
N.	L. 0	1	2	3	4	5	6	7	8	9	Prop. Parts

0° 10′ = 600″	S. 4.68 557	T. 4.68 558
0 11 = 660	557	558
0 12 = 720	557	558
1 48 = 6480	550	572
1 49 = 6540	550	572
1 50 = 6600	550	572

1° 51′ = 6660″	S. 4.68 5$\bar{5}$0	T. 4.68 573
1 52 = 6720	5$\bar{5}$0	573
1 53 = 6780	5$\bar{5}$0	573
1 54 = 6840	5$\bar{5}$0	573
1 55 = 6900	549	574
1 56 = 6960	549	574
1 57 = 7020	549	574

N.	L. 0	1	2	3	4	5	6	7	8	9
700	84 510	516	522	528	535̄	541	547	553	559	566
701	572	578	584	590	597	603	609	615	621	628
702	634	640	646	652	658	665̄	671	677	683	689
703	696	702	708	714	720	726	733	739	745̄	751
704	757	763	770	776	782	788	794	800	807	813
705	819	825	831	837	844	850̄	856	862	868	874
706	880	887	893	899	905	911	917	924	930	936
707	942	948	954	960	967	973	979	985̄	991	997
708	85 003	009	016	022	028	034	040	046	052	058
709	065̄	071	077	083	089	095	101	107	114	120
710	126	132	138	144	150	156	163	169	175̄	181
711	187	193	199	205	211	217	224	230	236	242
712	248	254	260	266	272	278	285̄	291	297	303
713	309	315	321	327	333	339	345	352	358	364
714	370	376	382	388	394	400	406	412	418	425̄
715	431	437	443	449	455̄	461	467	473	479	485
716	491	497	503	509	516	522	528	534	540	546
717	552	558	564	570	576	582	588	594	600	606
718	612	618	625̄	631	637	643	649	655̄	661	667
719	673	679	685̄	691	697	703	709	715	721	727
720	733	739	745	751	757	763	769	775	781	788
721	794	800	806	812	818	824	830	836	842	848
722	854	860	866	872	878	884	890	896	902	908
723	914	920	926	932	938	944	950	956	962	968
724	974	980	986	992	998	*004	*010	*016	*022	*028
725	86 034	040	046	052	058	064	070	076	082	088
726	094	100	106	112	118	124	130	136	141	147
727	153	159	165	171	177	183	189	195	201	207
728	213	219	225	231	237	243	249	255̄	261	267
729	273	279	285̄	291	297	303	308	314	320	326
730	332	338	344	350	356	362	368	374	380	386
731	392	398	404	410	415	421	427	433	439	445
732	451	457	463	469	475̄	481	487	493	499	504
733	510	516	522	528	534	540	546	552	558	564
734	570	576	581	587	593	599	605	611	617	623
735	629	635̄	641	646	652	658	664	670	676	682
736	688	694	700	705	711	717	723	729	735̄	741
737	747	753	759	764	770	776	782	788	794	800
738	806	812	817	823	829	835	841	847	853	859
739	864	870	876	882	888	894	900	906	911	917
740	923	929	935̄	941	947	953	958	964	970	976
741	982	988	994	999	*005	*011	*017	*023	*029	*035̄
742	87 040	046	052	058	064	070	075	081	087	093
743	099	105̄	111	116	122	128	134	140	146	151
744	157	163	169	175̄	181	186	192	198	204	210
745	216	221	227	233	239	245̄	251	256	262	268
746	274	280	286	291	297	303	309	315̄	320	326
747	332	338	344	349	355	361	367	373	379	384
748	390	396	402	408	413	419	425̄	431	437	442
749	448	454	460	466	471	477	483	489	495̄	500
750	506	512	518	523	529	535	541	547	552	558
N.	L. 0	1	2	3	4	5	6	7	8	9

Prop. Parts

	7
1	0.7
2	1.4
3	2.1
4	2.8
5	3.5
6	4.2
7	4.9
8	5.6
9	6.3

	6
1	0.6
2	1.2
3	1.8
4	2.4
5	3.0
6	3.6
7	4.2
8	4.8
9	5.4

	5
1	0.5
2	1.0
3	1.5
4	2.0
5	2.5
6	3.0
7	3.5
8	4.0
9	4.5

Prop. Parts

		S.	T.
0° 11′	= 660″	4.68 557	4.68 558
0 12	= 720	557	558
0 13	= 780	557	558
1 56	= 6960	549	574
1 57	= 7020	549	574
1 58	= 7080	549	575̄

		S.	T.
1° 59′	= 7140″	4.68 549	4.68 575̄
2 0	= 7200	549	575
2 1	= 7260	549	575
2 2	= 7320	548	576
2 3	= 7380	548	576
2 4	= 7440	548	576
2 5	= 7500	548	577

N.	L. 0	1	2	3	4	5	6	7	8	9
750	87 506	512	518	523	529	535	541	547	552	558
751	564	570	576	581	587	593	599	604	610	616
752	622	628	633	639	645	651	656	662	668	674
753	679	685	691	697	703	708	714	720	726	731
754	737	743	749	754	760	766	772	777	783	789
755	795	800	806	812	818	823	829	835	841	846
756	852	858	864	869	875	881	887	892	898	904
757	910	915	921	927	933	938	944	950	955	961
758	967	973	978	984	990	996	*001	*007	*013	*018
759	88 024	030	036	041	047	053	058	064	070	076
760	081	087	093	098	104	110	116	121	127	133
761	138	144	150	156	161	167	173	178	184	190
762	195	201	207	213	218	224	230	235	241	247
763	252	258	264	270	275	281	287	292	298	304
764	309	315	321	326	332	338	343	349	355	360
765	366	372	377	383	389	395	400	406	412	417
766	423	429	434	440	446	451	457	463	468	474
767	480	485	491	497	502	508	513	519	525	530
768	536	542	547	553	559	564	570	576	581	587
769	593	598	604	610	615	621	627	632	638	643
770	649	655	660	666	672	677	683	689	694	700
771	705	711	717	722	728	734	739	745	750	756
772	762	767	773	779	784	790	795	801	807	812
773	818	824	829	835	840	846	852	857	863	868
774	874	880	885	891	897	902	908	913	919	925
775	930	936	941	947	953	958	964	969	975	981
776	986	992	997	*003	*009	*014	*020	*025	*031	*037
777	89 042	048	053	059	064	070	076	081	087	092
778	098	104	109	115	120	126	131	137	143	148
779	154	159	165	170	176	182	187	193	198	204
780	209	215	221	226	232	237	243	248	254	260
781	265	271	276	282	287	293	298	304	310	315
782	321	326	332	337	343	348	354	360	365	371
783	376	382	387	393	398	404	409	415	421	426
784	432	437	443	448	454	459	465	470	476	481
785	487	492	498	504	509	515	520	526	531	537
786	542	548	553	559	564	570	575	581	586	592
787	597	603	609	614	620	625	631	636	642	647
788	653	658	664	669	675	680	686	691	697	702
789	708	713	719	724	730	735	741	746	752	757
790	763	768	774	779	785	790	796	801	807	812
791	818	823	829	834	840	845	851	856	862	867
792	873	878	883	889	894	900	905	911	916	922
793	927	933	938	944	949	955	960	966	971	977
794	982	988	993	998	*004	*009	*015	*020	*026	*031
795	90 037	042	048	053	059	064	069	075	080	086
796	091	097	102	108	113	119	124	129	135	140
797	146	151	157	162	168	173	179	184	189	195
798	200	206	211	217	222	227	233	238	244	249
799	255	260	266	271	276	282	287	293	298	304
800	309	314	320	325	331	336	342	347	352	358
N.	L. 0	1	2	3	4	5	6	7	8	9

Prop. Parts

	6
1	0.6
2	1.2
3	1.8
4	2.4
5	3.0
6	3.6
7	4.2
8	4.8
9	5.4

	5
1	0.5
2	1.0
3	1.5
4	2.0
5	2.5
6	3.0
7	3.5
8	4.0
9	4.5

		S.	T.
0° 12′	= 720″	4.68 557	4.68 558
0 13	= 780	557	558
0 14	= 840	557	558
2 5	= 7500	548	577
2 6	= 7560	548	577
2 7	= 7620	548	577
2° 8′	= 7680″	4.68 547	4.68 578
2 9	= 7740	547	578
2 10	= 7800	547	578
2 11	= 7860	547	579
2 12	= 7920	547	579
2 13	= 7980	547	579
2 14	= 8040	546	579

N.	L. 0	1	2	3	4	5	6	7	8	9
800	90 309	314	320	325	331	336	342	347	352	358
801	363	369	374	380	38$\bar{5}$	390	396	401	407	412
802	417	423	428	434	439	44$\bar{5}$	4$\bar{5}$0	455	461	466
803	472	477	482	488	493	499	504	509	51$\bar{5}$	520
804	526	531	536	542	547	553	558	563	569	574
805	580	58$\bar{5}$	590	596	601	607	612	617	623	628
806	634	639	644	6$\bar{5}$0	655	660	666	671	677	682
807	687	693	698	703	709	714	720	725	730	736
808	741	747	752	757	763	768	773	779	784	789
809	79$\bar{5}$	800	806	811	816	822	827	832	838	843
810	849	854	859	86$\bar{5}$	870	875	881	886	891	897
811	902	907	913	918	924	929	934	940	94$\bar{5}$	950
812	956	961	966	972	977	982	988	993	998	*004
813	91 009	014	020	025	030	036	041	046	052	057
814	062	068	073	078	084	089	094	100	105	110
815	116	121	126	132	137	142	148	153	158	164
816	169	174	180	18$\bar{5}$	190	196	201	206	212	217
817	222	228	233	238	243	249	254	259	26$\bar{5}$	270
818	275	281	286	291	297	302	307	312	318	323
819	328	334	339	344	3$\bar{5}$0	35$\bar{5}$	360	365	371	376
820	381	387	392	397	403	408	413	418	424	429
821	434	440	44$\bar{5}$	450	455	461	466	471	477	482
822	487	492	498	503	508	514	519	524	529	53$\bar{5}$
823	540	545	551	556	561	566	572	577	582	587
824	593	598	603	609	614	619	624	630	63$\bar{5}$	640
825	645	651	656	661	666	672	677	682	687	693
826	698	703	709	714	719	724	730	73$\bar{5}$	740	745
827	751	756	761	766	772	777	782	787	793	798
828	803	808	814	819	824	829	834	840	84$\bar{5}$	850
829	855	861	866	871	876	882	887	892	897	903
830	908	913	918	924	929	934	939	944	9$\bar{5}$0	95$\bar{5}$
831	960	965	971	976	981	986	991	997	*002	*007
832	92 012	018	023	028	033	038	044	049	054	059
833	06$\bar{5}$	070	07$\bar{5}$	080	085	091	096	101	106	111
834	117	122	127	132	137	143	148	153	158	163
835	169	174	179	184	189	19$\bar{5}$	200	205	210	215
836	221	226	231	236	241	247	252	257	262	267
837	273	278	283	288	293	298	304	309	314	319
838	324	330	33$\bar{5}$	340	345	350	355	361	366	371
839	376	381	387	392	397	402	407	412	418	423
840	428	433	438	443	449	454	459	464	469	474
841	480	48$\bar{5}$	490	495	500	505	511	516	521	526
842	531	536	542	547	552	557	562	567	572	578
843	583	588	593	598	603	609	614	619	624	629
844	634	639	64$\bar{5}$	6$\bar{5}$0	65$\bar{5}$	660	665	670	675	681
845	686	691	696	701	706	711	716	722	727	732
846	737	742	747	752	758	763	768	773	778	783
847	788	793	799	804	809	814	819	824	829	834
848	840	84$\bar{5}$	8$\bar{5}$0	85$\bar{5}$	860	865	870	875	881	886
849	891	896	901	906	911	916	921	927	932	937
850	942	947	952	957	962	967	973	978	983	988
N.	L. 0	1	2	3	4	5	6	7	8	9

Prop. Parts

	6
1	0.6
2	1.2
3	1.8
4	2.4
5	3.0
6	3.6
7	4.2
8	4.8
9	5.4

	5
1	0.5
2	1.0
3	1.5
4	2.0
5	2.5
6	3.0
7	3.5
8	4.0
9	4.5

Prop. Parts

		S.	T.
0° 13′	= 780″	4.68 557	4.68 558
0 14	= 840	557	558
0 15	= 900	557	558
2 13	=7980	547	579
2 14	=8040	546	579
2 15	=8100	546	580
2° 16′	=8160″	4.68 546	4.68 580
2 17	=8220	546	580
2 18	=8280	546	581
2 19	=8340	546	581
2 20	=8400	545	582
2 21	=8460	545	582
2 22	=8520	545	582

N.	L. 0	1	2	3	4	5	6	7	8	9
850	92 942	947	952	957	962	967	973	978	983	988
851	993	998	*003	*008	*013	*018	*024	*029	*034	*039
852	93 044	049	054	059	064	069	075̄	080	085̄	090
853	095̄	100	105	110	115	120	125	131	136	141
854	146	151	156	161	166	171	176	181	186	192
855	197	202	207	212	217	222	227	232	237	242
856	247	252	258	263	268	273	278	283	288	293
857	298	303	308	313	318	323	328	334	339	344
858	349	354	359	364	369	374	379	384	389	394
859	399	404	409	414	420	425̄	430	435̄	440	445̄
860	4̄50	455̄	460	465̄	470	475	480	485	490	495
861	500	505	510	515	520	526	531	536	541	546
862	551	556	561	566	571	576	581	586	591	596
863	601	606	611	616	621	626	631	636	641	646
864	651	656	661	666	671	676	682	687	692	697
865	702	707	712	717	722	727	732	737	742	747
866	752	757	762	767	772	777	782	787	792	797
867	802	807	812	817	822	827	832	837	842	847
868	852	857	862	867	872	877	882	887	892	897
869	902	907	912	917	922	927	932	937	942	947
870	952	957	962	967	972	977	982	987	992	997
871	94 002	007	012	017	022	027	032	037	042	047
872	052	057	062	067	072	077	082	086	091	096
873	101	106	111	116	121	126	131	136	141	146
874	151	156	161	166	171	176	181	186	191	196
875	201	206	211	216	221	226	231	236	240	245
876	250	255	260	265	270	275	280	285	290	295
877	300	305̄	310	315̄	320	325̄	330	335̄	340	345̄
878	349	354	359	364	369	374	379	384	389	394
879	399	404	409	414	419	424	429	433	438	443
880	448	453	458	463	468	473	478	483	488	493
881	498	503	507	512	517	522	527	532	537	542
882	547	552	557	562	567	571	576	581	586	591
883	596	601	606	611	616	621	626	630	635	640
884	645	650	655	660	665̄	670	675̄	680	685̄	689
885	694	699	704	709	714	719	724	729	734	738
886	743	748	753	758	763	768	773	778	783	787
887	792	797	802	807	812	817	822	827	832	836
888	841	846	851	856	861	866	871	876	880	885
889	890	895	900	905̄	910	915̄	919	924	929	934
890	939	944	949	954	959	963	968	973	978	983
891	988	993	998	*002	*007	*012	*017	*022	*027	*032
892	95 036	041	046	051	056	061	066	071	075	080
893	085	090	095̄	100	105̄	109	114	119	124	129
894	134	139	143	148	153	158	163	168	173	177
895	182	187	192	197	202	207	211	216	221	226
896	231	236	240	245	250	255	260	265̄	270	274
897	279	284	289	294	299	303	308	313	318	323
898	328	332	337	342	347	352	357	361	366	371
899	376	381	386	390	395	400	405̄	410	415̄	419
900	424	429	434	439	444	448	453	458	463	468
N.	L. 0	1	2	3	4	5	6	7	8	9

Prop. Parts

	6
1	0.6
2	1.2
3	1.8
4	2.4
5	3.0
6	3.6
7	4.2
8	4.8
9	5.4

	5
1	0.5
2	1.0
3	1.5
4	2.0
5	2.5
6	3.0
7	3.5
8	4.0
9	4.5

	4
1	0.4
2	0.8
3	1.2
4	1.6
5	2.0
6	2.4
7	2.8
8	3.2
9	3.6

Prop. Parts

		S.	T.
0° 14′	= 840″	S. 4.68 557	T. 4.68 558
0 15	= 900	557	558
2 21	= 8460	545	582
2 22	= 8520	545	582
2 23	= 8580	545̄	583
2 24	= 8640	545̄	583
2° 25′	= 8700″	S. 4.68 545̄	T. 4.68 583
2 26	= 8760	544	584
2 27	= 8820	544	584
2 28	= 8880	544	584
2 29	= 8940	544	585̄
2 30	= 9000	544	585

N.	L. 0	1	2	3	4	5	6	7	8	9	Prop. Parts
900	95 424	429	434	439	444	448	453	458	463	468	
901	472	477	482	487	492	497	501	506	511	516	
902	521	525	530	535	540	545	550	554	559	564	
903	569	574	578	583	588	593	598	602	607	612	
904	617	622	626	631	636	641	646	650	655	660	
905	665	670	674	679	684	689	694	698	703	708	
906	713	718	722	727	732	737	742	746	751	756	
907	761	766	770	775	780	785	789	794	799	804	
908	809	813	818	823	828	832	837	842	847	852	
909	856	861	866	871	875	880	885	890	895	899	
910	904	909	914	918	923	928	933	938	942	947	**5**
911	952	957	961	966	971	976	980	985	990	995	1 | 0.5
912	999	*004	*009	*014	*019	*023	*028	*033	*038	*042	2 | 1.0
913	96 047	052	057	061	066	071	076	080	085	090	3 | 1.5
914	095	099	104	109	114	118	123	128	133	137	4 | 2.0
915	142	147	152	156	161	166	171	175	180	185	5 | 2.5
916	190	194	199	204	209	213	218	223	227	232	6 | 3.0
917	237	242	246	251	256	261	265	270	275	280	7 | 3.5
918	284	289	294	298	303	308	313	317	322	327	8 | 4.0
919	332	336	341	346	350	355	360	365	369	374	9 | 4.5
920	379	384	388	393	398	402	407	412	417	421	
921	426	431	435	440	445	450	454	459	464	468	
922	473	478	483	487	492	497	501	506	511	515	
923	520	525	530	534	539	544	548	553	558	562	
924	567	572	577	581	586	591	595	600	605	609	
925	614	619	624	628	633	638	642	647	652	656	
926	661	666	670	675	680	685	689	694	699	703	
927	708	713	717	722	727	731	736	741	745	750	
928	755	759	764	769	774	778	783	788	792	797	
929	802	806	811	816	820	825	830	834	839	844	
930	848	853	858	862	867	872	876	881	886	890	**4**
931	895	900	904	909	914	918	923	928	932	937	1 | 0.4
932	942	946	951	956	960	965	970	974	979	984	2 | 0.8
933	988	993	997	*002	*007	*011	*016	*021	*025	*030	3 | 1.2
934	97 035	039	044	049	053	058	063	067	072	077	4 | 1.6
935	081	086	090	095	100	104	109	114	118	123	5 | 2.0
936	128	132	137	142	146	151	155	160	165	169	6 | 2.4
937	174	179	183	188	192	197	202	206	211	216	7 | 2.8
938	220	225	230	234	239	243	248	253	257	262	8 | 3.2
939	267	271	276	280	285	290	294	299	304	308	9 | 3.6
940	313	317	322	327	331	336	340	345	350	354	
941	359	364	368	373	377	382	387	391	396	400	
942	405	410	414	419	424	428	433	437	442	447	
943	451	456	460	465	470	474	479	483	488	493	
944	497	502	506	511	516	520	525	529	534	539	
945	543	548	552	557	562	566	571	575	580	585	
946	589	594	598	603	607	612	617	621	626	630	
947	635	640	644	649	653	658	663	667	672	676	
948	681	685	690	695	699	704	708	713	717	722	
949	727	731	736	740	745	749	754	759	763	768	
950	772	777	782	786	791	795	800	804	809	813	
N.	L. 0	1	2	3	4	5	6	7	8	9	Prop. Parts

0° 15′ = 900″	S. 4.68 557	T. 4.68 558	2° 34′ = 9240″	S. 4.68 543	T. 4.68 587
0 16 = 960	557	558	2 35 = 9300	543	587
			2 36 = 9360	543	587
2 30 = 9000	544	585	2 37 = 9420	542	588
2 31 = 9060	544	585	2 38 = 9480	542	588
2 32 = 9120	543	586	2 39 = 9540	542	588
2 33 = 9180	543	586			

N.	L.	0	1	2	3	4	5	6	7	8	9
950	97	772	777	782	786	791	795	800	804	809	813
951		818	823	827	832	836	841	845	850	855	859
952		864	868	873	877	882	886	891	896	900	905
953		909	914	918	923	928	932	937	941	946	950
954		955	959	964	968	973	978	982	987	991	996
955	98	000	005	009	014	019	023	028	032	037	041
956		046	050	055	059	064	068	073	078	082	087
957		091	096	100	105	109	114	118	123	127	132
958		137	141	146	150	155	159	164	168	173	177
959		182	186	191	195	200	204	209	214	218	223
960		227	232	236	241	245	250	254	259	263	268
961		272	277	281	286	290	295	299	304	308	313
962		318	322	327	331	336	340	345	349	354	358
963		363	367	372	376	381	385	390	394	399	403
964		408	412	417	421	426	430	435	439	444	448
965		453	457	462	466	471	475	480	484	489	493
966		498	502	507	511	516	520	525	529	534	538
967		543	547	552	556	561	565	570	574	579	583
968		588	592	597	601	605	610	614	619	623	628
969		632	637	641	646	650	655	659	664	668	673
970		677	682	686	691	695	700	704	709	713	717
971		722	726	731	735	740	744	749	753	758	762
972		767	771	776	780	784	789	793	798	802	807
973		811	816	820	825	829	834	838	843	847	851
974		856	860	865	869	874	878	883	887	892	896
975		900	905	909	914	918	923	927	932	936	941
976		945	949	954	958	963	967	972	976	981	985
977		989	994	998	*003	*007	*012	*016	*021	*025	*029
978	99	034	038	043	047	052	056	061	065	069	074
979		078	083	087	092	096	100	105	109	114	118
980		123	127	131	136	140	145	149	154	158	162
981		167	171	176	180	185	189	193	198	202	207
982		211	216	220	224	229	233	238	242	247	251
983		255	260	264	269	273	277	282	286	291	295
984		300	304	308	313	317	322	326	330	335	339
985		344	348	352	357	361	366	370	374	379	383
986		388	392	396	401	405	410	414	419	423	427
987		432	436	441	445	449	454	458	463	467	471
988		476	480	484	489	493	498	502	506	511	515
989		520	524	528	533	537	542	546	550	555	559
990		564	568	572	577	581	585	590	594	599	603
991		607	612	616	621	625	629	634	638	642	647
992		651	656	660	664	669	673	677	682	686	691
993		695	699	704	708	712	717	721	726	730	734
994		739	743	747	752	756	760	765	769	774	778
995		782	787	791	795	800	804	808	813	817	822
996		826	830	835	839	843	848	852	856	861	865
997		870	874	878	883	887	891	896	900	904	909
998		913	917	922	926	930	935	939	944	948	952
999		957	961	965	970	974	978	983	987	991	996
1000	00	000	004	009	013	017	022	026	030	035	039

Prop. Parts

	5
1	0.5
2	1.0
3	1.5
4	2.0
5	2.5
6	3.0
7	3.5
8	4.0
9	4.5

	4
1	0.4
2	0.8
3	1.2
4	1.6
5	2.0
6	2.4
7	2.8
8	3.2
9	3.6

		S.	T.
0° 15′	= 900″	4.68 557	4.68 558
0 16	= 960	557	558
0 17	= 1020	557	558
2 38	= 9480	542	588
2 39	= 9540	542	588
2 40	= 9600	542	589
2° 41′	= 9660″	4.68 542	4.68 589
2 42	= 9720	541	590
2 43	= 9780	541	590
2 44	= 9840	541	590
2 45	= 9900	541	591
2 46	= 9960	541	591
2 47	= 10020	540	592

1000-1050

N.	L. 0	1	2	3	4	5	6	7	8	9
1000	000 0000	0434	0869	1303	1737	2171	2605	3039	3473	3907
1001	4341	4775	5208	5642	6076	6510	6943	7377	7810	8244
1002	8677	9111	9544	9977	*0411	*0844	*1277	*1710	*2143	*2576
1003	001 3009	3442	3875	4308	4741	5174	5607	6039	6472	6905
1004	7337	7770	8202	8635	9067	9499	9932	*0364	*0796	*1228
1005	002 1661	2093	2525	2957	3389	3821	4253	4685	5116	5548
1006	5980	6411	6843	7275	7706	8138	8569	9001	9432	9863
1007	003 0295	0726	1157	1588	2019	2451	2882	3313	3744	4174
1008	4605	5036	5467	5898	6328	6759	7190	7620	8051	8481
1009	8912	9342	9772	*0203	*0633	*1063	*1493	*1924	*2354	*2784
1010	004 3214	3644	4074	4504	4933	5363	5793	6223	6652	7082
1011	7512	7941	8371	8800	9229	9659	*0088	*0517	*0947	*1376
1012	005 1805	2234	2663	3092	3521	3950	4379	4808	5237	5666
1013	6094	6523	6952	7380	7809	8238	8666	9094	9523	9951
1014	006 0380	0808	1236	1664	2092	2521	2949	3377	3805	4233
1015	4660	5088	5516	5944	6372	6799	7227	7655	8082	8510
1016	8937	9365	9792	*0219	*0647	*1074	*1501	*1928	*2355	*2782
1017	007 3210	3637	4064	4490	4917	5344	5771	6198	6624	7051
1018	7478	7904	8331	8757	9184	9610	*0037	*0463	*0889	*1316
1019	008 1742	2168	2594	3020	3446	3872	4298	4724	5150	5576
1020	6002	6427	6853	7279	7704	8130	8556	8981	9407	9832
1021	009 0257	0683	1108	1533	1959	2384	2809	3234	3659	4084
1022	4509	4934	5359	5784	6208	6633	7058	7483	7907	8332
1023	8756	9181	9605	*0030	*0454	*0878	*1303	*1727	*2151	*2575
1024	010 3000	3424	3848	4272	4696	5120	5544	5967	6391	6815
1025	7239	7662	8086	8510	8933	9357	9780	*0204	*0627	*1050
1026	011 1474	1897	2320	2743	3166	3590	4013	4436	4859	5282
1027	5704	6127	6550	6973	7396	7818	8241	8664	9086	9509
1028	9931	*0354	*0776	*1198	*1621	*2043	*2465	*2887	*3310	*3732
1029	012 4154	4576	4998	5420	5842	6264	6685	7107	7529	7951
1030	8372	8794	9215	9637	*0059	*0480	*0901	*1323	*1744	*2165
1031	013 2587	3008	3429	3850	4271	4692	5113	5534	5955	6376
1032	6797	7218	7639	8059	8480	8901	9321	9742	*0162	*0583
1033	014 1003	1424	1844	2264	2685	3105	3525	3945	4365	4785
1034	5205	5625	6045	6465	6885	7305	7725	8144	8564	8984
1035	9403	9823	*0243	*0662	*1082	*1501	*1920	*2340	*2759	*3178
1036	015 3598	4017	4436	4855	5274	5693	6112	6531	6950	7369
1037	7788	8206	8625	9044	9462	9881	*0300	*0718	*1137	*1555
1038	016 1974	2392	2810	3229	3647	4065	4483	4901	5319	5737
1039	6155	6573	6991	7409	7827	8245	8663	9080	9498	9916
1040	017 0333	0751	1168	1586	2003	2421	2838	3256	3673	4090
1041	4507	4924	5342	5759	6176	6593	7010	7427	7844	8260
1042	8677	9094	9511	9927	*0344	*0761	*1177	*1594	*2010	*2427
1043	018 2843	3259	3676	4092	4508	4925	5341	5757	6173	6589
1044	7005	7421	7837	8253	8669	9084	9500	9916	*0332	*0747
1045	019 1163	1578	1994	2410	2825	3240	3656	4071	4486	4902
1046	5317	5732	6147	6562	6977	7392	7807	8222	8637	9052
1047	9467	9882	*0296	*0711	*1126	*1540	*1955	*2369	*2784	*3198
1048	020 3613	4027	4442	4856	5270	5684	6099	6513	6927	7341
1049	7755	8169	8583	8997	9411	9824	*0238	*0652	*1066	*1479
1050	021 1893	2307	2720	3134	3547	3961	4374	4787	5201	5614
N.	L. 0	1	2	3	4	5	6	7	8	9

2° 46′ = 9 960″	S. 4.68 541	T. 4.68 591		2° 51′ = 10 260″	S. 4.68 540	T. 4.68 593
2 47 = 10 020	540	592		2 52 = 10 320	539	594
2 48 = 10 080	540	592		2 53 = 10 380	539	594
2 49 = 10 140	540	592		2 54 = 10 440	539	595
2 50 = 10 200	540	593		2 55 = 10 500	539	595

N.	L.	0	1	2	3	4	5	6	7	8	9
1050	021	1893	2307	2720	3134	3547	3961	4374	4787	5201	5614
1051		6027	6440	6854	7267	7680	8093	8506	8919	9332	9745
1052	022	0157	0570	0983	1396	1808	2221	2634	3046	3459	3871
1053		4284	4696	5109	5521	5933	6345	6758	7170	7582	7994
1054		8406	8818	9230	9642	*0054	*0466	*0878	*1289	*1701	*2113
1055	023	2525	2936	3348	3759	4171	4582	4994	5405	5817	6228
1056		6639	7050	7462	7873	8284	8695	9106	9517	9928	*0339
1057	024	0750	1161	1572	1982	2393	2804	3214	3625	4036	4446
1058		4857	5267	5678	6088	6498	6909	7319	7729	8139	8549
1059		8960	9370	9780	*0190	*0600	*1010	*1419	*1829	*2239	*2649
1060	025	3059	3468	3878	4288	4697	5107	5516	5926	6335	6744
1061		7154	7563	7972	8382	8791	9200	9609	*0018	*0427	*0836
1062	026	1245	1654	2063	2472	2881	3289	3698	4107	4515	4924
1063		5333	5741	6150	6558	6967	7375	7783	8192	8600	9008
1064		9416	9824	*0233	*0641	*1049	*1457	*1865	*2273	*2680	*3088
1065	027	3496	3904	4312	4719	5127	5535	5942	6350	6757	7165
1066		7572	7979	8387	8794	9201	9609	*0016	*0423	*0830	*1237
1067	028	1644	2051	2458	2865	3272	3679	4086	4492	4899	5306
1068		5713	6119	6526	6932	7339	7745	8152	8558	8964	9371
1069		9777	*0183	*0590	*0996	*1402	*1808	*2214	*2620	*3026	*3432
1070	029	3838	4244	4649	5055	5461	5867	6272	6678	7084	7489
1071		7895	8300	8706	9111	9516	9922	*0327	*0732	*1138	*1543
1072	030	1948	2353	2758	3163	3568	3973	4378	4783	5188	5592
1073		5997	6402	6807	7211	7616	8020	8425	8830	9234	9638
1074	031	0043	0447	0851	1256	1660	2064	2468	2872	3277	3681
1075		4085	4489	4893	5296	5700	6104	6508	6912	7315	7719
1076		8123	8526	8930	9333	9737	*0140	*0544	*0947	*1350	*1754
1077	032	2157	2560	2963	3367	3770	4173	4576	4979	5382	5785
1078		6188	6590	6993	7396	7799	8201	8604	9007	9409	9812
1079	033	0214	0617	1019	1422	1824	2226	2629	3031	3433	3835
1080		4238	4640	5042	5444	5846	6248	6650	7052	7453	7855
1081		8257	8659	9060	9462	9864	*0265	*0667	*1068	*1470	*1871
1082	034	2273	2674	3075	3477	3878	4279	4680	5081	5482	5884
1083		6285	6686	7087	7487	7888	8289	8690	9091	9491	9892
1084	035	0293	0693	1094	1495	1895	2296	2696	3096	3497	3897
1085		4297	4698	5098	5498	5898	6298	6698	7098	7498	7898
1086		8298	8698	9098	9498	9898	*0297	*0697	*1097	*1496	*1896
1087	036	2295	2695	3094	3494	3893	4293	4692	5091	5491	5890
1088		6289	6688	7087	7486	7885	8284	8683	9082	9481	9880
1089	037	0279	0678	1076	1475	1874	2272	2671	3070	3468	3867
1090		4265	4663	5062	5460	5858	6257	6655	7053	7451	7849
1091		8248	8646	9044	9442	9839	*0237	*0635	*1033	*1431	*1829
1092	038	2226	2624	3022	3419	3817	4214	4612	5009	5407	5804
1093		6202	6599	6996	7393	7791	8188	8585	8982	9379	9776
1094	039	0173	0570	0967	1364	1761	2158	2554	2951	3348	3745
1095		4141	4538	4934	5331	5727	6124	6520	6917	7313	7709
1096		8106	8502	8898	9294	9690	*0086	*0482	*0878	*1274	*1670
1097	040	2066	2462	2858	3254	3650	4045	4441	4837	5232	5628
1098		6023	6419	6814	7210	7605	8001	8396	8791	9187	9582
1099		9977	*0372	*0767	*1162	*1557	*1952	*2347	*2742	*3137	*3532
1100	041	3927	4322	4716	5111	5506	5900	6295	6690	7084	7479
N.	L.	0	1	2	3	4	5	6	7	8	9

2° 55′=10 500″	S. 4.68 539	T. 4.68 595		3° 0′=10 800″	S. 4.68 538	T. 4.68 597
2 56 =10 560	539	595		3 1 =10 860	537	598
2 57 =10 620	538	596		3 2 =10 920	537	598
2 58 =10 680	538	596		3 3 =10 980	537	599
2 59 =10 740	538	597		3 4 =11 040	537	599

TABLE II[1]

LOGARITHMS OF TRIGONOMETRIC FUNCTIONS

Use of Table for Angles near 0° and 90°. When angles are near 0° or near 90°, interpolation based on the assumption of proportional change in angle and logarithm may give results considerably in error. For this reason it is convenient to introduce the functions S and T defined by the equations $S = \alpha/\sin\alpha$ and $T = \alpha/\tan\alpha$. The relative change of the functions S and T with respect to α is very small when α is less than 3° and, as a consequence, the required accuracy of the results is obtained by using them. On the first three pages of Table II the columns headed log S* and log T give the common logarithms of S and T, respectively. The following formulas apply when the angle involved is less than 3°:

1. For angles less in magnitude than 3°.

(*a*) $\log\sin\alpha = \log\alpha''$† $- \log S$.
(*b*) $\log\tan\alpha = \log\alpha'' - \log T$.
(*c*) $\log\cot\alpha = \text{colog}\,\alpha'' + \log T$,
$\qquad = \text{colog}\tan\alpha$.
(*d*) $\log\csc\alpha = \text{colog}\,\alpha'' + \log S$.
(*e*) $\log\alpha'' = \log\sin\alpha + \log S$.
(*f*) $\log\alpha'' = \log\tan\alpha + \log T$.
(*g*) $\log\alpha'' = \text{colog}\cot\alpha + \log T$.
(*h*) $\log\alpha'' = \text{colog}\csc\alpha + \log S$.

2. For angles α such that $90° - \alpha$‡ is less in magnitude than 3°.

(*i*) $\log\cos\alpha = \log(90° - \alpha)'' - \log S$.
(*j*) $\log\cot\alpha = \log(90° - \alpha)'' - \log T$.
(*k*) $\log\tan\alpha = \text{colog}\,(90° - \alpha)'' + \log T$,
$\qquad = \text{colog}\cot\alpha$.
(*l*) $\log\sec\alpha = \text{colog}\,(90° - \alpha)'' + \log S$.
(*m*) $\log(90° - \alpha)'' = \log\cos\alpha + \log S$.
(*n*) $\log(90° - \alpha)'' = \log\cot\alpha + \log T$.
(*o*) $\log(90° - \alpha)'' = \text{colog}\tan\alpha + \log T$.
(*p*) $\log(90° - \alpha)'' = \text{colog}\sec\alpha + \log S$.

To find θ when $\log\sin\theta = 8.46932 - 10$, we first find in the column headed l sin the entry nearest to 8.46932, namely, 8.46799. On one side of 8.46799 we read $\log S = 5.31449$, and on the other $1°41' = 6060''$. Hence, using formula (*e*), we write $\log\alpha = 8.46932 - 10 + 5.31449 = 3.78381$. Therefore $\alpha = 6078.7''$. Since $1°41' = 6060''$, $6078.7'' = 1°41'19''$.

[1] From "Plane Trigonometry," by Lyman M. Kells, Willis F. Kern, and James R. Bland, used by permission of the publishers, McGraw-Hill Book Company, Inc., New York.

* The function log S is often written cpl S, and the function log T, is written cpl T.

† The symbol $\log\alpha''$ means in this connection the logarithm of the number of seconds in the angle.

‡ Since $\cos\alpha = \sin(90° - \alpha)$, in this case $S = \dfrac{(90° - \alpha)''}{\sin(90° - \alpha)}$.

″	′	l sin	log S	l csc	l tan	log T	l cot	l sec	l cos	′
0	**0**	Inf. neg.	—	Infinite.	Inf. neg.	—	Infinite.	10.00000	10.00000	**60**
60	1	6.46373	5.31 443	13.53627	6.46373	5.31 443	13.53627	00000	00000	59
120	2	76476	5.31 443	23524	76476	5.31 443	23524	00000	00000	58
180	3	94085	5.31 443	05915	94085	5.31 443	05915	00000	00000	57
240	4	7.06579	5.31 443	12.93421	7.06579	5.31 442	12.93421	00000	00000	56
300	**5**	7.16270	5.31 443	12.83730	7.16270	5.31 442	12.83730	10.00000	10.00000	**55**
360	6	24188	5.31 443	75812	24188	5.31 442	75812	00000	00000	54
420	7	30882	5.31 443	69118	30882	5.31 442	69118	00000	00000	53
480	8	36682	5.31 443	63318	36682	5.31 442	63318	00000	00000	52
540	9	41797	5.31 443	58203	41797	5.31 442	58203	00000	00000	51
600	**10**	7.46373	5.31 443	12.53627	7.46373	5.31 442	12.53627	10.00000	10.00000	**50**
660	11	50512	5.31 443	49488	50512	5.31 442	49488	00000	00000	49
720	12	54291	5.31 443	45709	54291	5.31 442	45709	00000	00000	48
780	13	57767	5.31 443	42233	57767	5.31 442	42233	00000	00000	47
840	14	60985	5.31 443	39015	60986	5.31 442	39014	00000	00000	46
900	**15**	7.63982	5.31 443	12.36018	7.63982	5.31 442	12.36018	10.00000	10.00000	**45**
960	16	66784	5.31 443	33216	66785	5.31 442	33215	00000	00000	44
1020	17	69417	5.31 443	30583	69418	5.31 442	30582	00001	9.99999	43
1080	18	71900	5.31 443	28100	71900	5.31 442	28100	00001	99999	42
1140	19	74248	5.31 443	25752	74248	5.31 442	25752	00001	99999	41
1200	**20**	7.76475	5.31 443	12.23525	7.76476	5.31 442	12.23524	10.00001	9.99999	**40**
1260	21	78594	5.31 443	21406	78595	5.31 442	21405	00001	99999	39
1320	22	80615	5.31 443	19385	80615	5.31 442	19385	00001	99999	38
1380	23	82545	5.31 443	17455	82546	5.31 442	17454	00001	99999	37
1440	24	84393	5.31 443	15607	84394	5.31 442	15606	00001	99999	36
1500	**25**	7.86166	5.31 443	12.13834	7.86167	5.31 442	12.13833	10.00001	9.99999	**35**
1560	26	87870	5.31 443	12130	87871	5.31 442	12129	00001	99999	34
1620	27	89509	5.31 443	10491	89510	5.31 442	10490	00001	99999	33
1680	28	91088	5.31 443	08912	91089	5.31 442	08911	00001	99999	32
1740	29	92612	5.31 443	07388	92613	5.31 441	07387	00002	99998	31
1800	**30**	7.94084	5.31 443	12.05916	7.94086	5.31 441	12.05914	10.00002	9.99998	**30**
1860	31	95508	5.31 443	04492	95510	5.31 441	04490	00002	99998	29
1920	32	96887	5.31 443	03113	96889	5.31 441	03111	00002	99998	28
1980	33	98223	5.31 443	01777	98225	5.31 441	01775	00002	99998	27
2040	34	99520	5.31 443	00480	99522	5.31 441	00478	00002	99998	26
2100	**35**	8.00779	5.31 443	11.99221	8.00781	5.31 441	11.99219	10.00002	9.99998	**25**
2160	36	02002	5.31 443	97998	02004	5.31 441	97996	00002	99998	24
2220	37	03192	5.31 443	96808	03194	5.31 441	96806	00003	99997	23
2280	38	04350	5.31 443	95650	04353	5.31 441	95647	00003	99997	22
2340	39	05478	5.31 443	94522	05481	5.31 441	94519	00003	99997	21
2400	**40**	8.06578	5.31 443	11.93422	8.06581	5.31 441	11.93419	10.00003	9.99997	**20**
2460	41	07650	5.31 444	92350	07653	5.31 440	92347	00003	99997	19
2520	42	08696	5.31 444	91304	08700	5.31 440	91300	00003	99997	18
2580	43	09718	5.31 444	90282	09722	5.31 440	90278	00003	99997	17
2640	44	10717	5.31 444	89283	10720	5.31 440	89280	00004	99996	16
2700	**45**	8.11693	5.31 444	11.88307	8.11696	5.31 440	11.88304	10.00004	9.99996	**15**
2760	46	12647	5.31 444	87353	12651	5.31 440	87349	00004	99996	14
2820	47	13581	5.31 444	86419	13585	5.31 440	86415	00004	99996	13
2880	48	14495	5.31 444	85505	14500	5.31 440	85500	00004	99996	12
2940	49	15391	5.31 444	84609	15395	5.31 440	84605	00004	99996	11
3000	**50**	8.16268	5.31 444	11.83732	8.16273	5.31 439	11.83727	10.00005	9.99995	**10**
3060	51	17128	5.31 444	82872	17133	5.31 439	82867	00005	99995	9
3120	52	17971	5.31 444	82029	17976	5.31 439	82024	00005	99995	8
3180	53	18798	5.31 444	81202	18804	5.31 439	81196	00005	99995	7
3240	54	19610	5.31 444	80390	19616	5.31 439	80384	00005	99995	6
3300	**55**	8.20407	5.31 444	11.79593	8.20413	5.31 439	11.79587	10.00006	9.99994	**5**
3360	56	21189	5.31 444	78811	21195	5.31 439	78805	00006	99994	4
3420	57	21958	5.31 445	78042	21964	5.31 439	78036	00006	99994	3
3480	58	22713	5.31 445	77287	22720	5.31 438	77280	00006	99994	2
3540	59	23456	5.31 445	76544	23462	5.31 438	76538	00006	99994	1
3600	**60**	24186	5.31 445	75814	24192	5.31 438	75808	00007	99993	**0**
	′	l cos		l sec	l cot		l tan	l csc	l sin	′

″	′	*l* sin	log *S*	*l* csc	*l* tan	log *T*	*l* cot	*l* sec	*l* cos	′
3600	**0**	8.24186	5.31445	11.75814	8.24192	5.31438	11.75808	10.00007	9.99993	**60**
3660	1	24903	5.31445	75097	24910	5.31438	75090	00007	99993	59
3720	2	25609	5.31445	74391	25616	5.31438	74384	00007	99993	58
3780	3	26304	5.31445	73696	26312	5.31438	73688	00007	99993	57
3840	4	26988	5.31445	73012	26996	5.31437	73004	00008	99992	56
3900	**5**	8.27661	5.31445	11.72339	8.27669	5.31437	11.72331	10.00008	9.99992	**55**
3960	6	28324	5.31445	71676	28332	5.31437	71668	00008	99992	54
4020	7	28977	5.31445	71023	28986	5.31437	71014	00008	99992	53
4080	8	29621	5.31445	70379	29629	5.31437	70371	00008	99992	52
4140	9	30255	5.31445	69745	30263	5.31437	69737	00009	99991	51
4200	**10**	8.30879	5.31446	11.69121	8.30888	5.31437	11.69112	10.00009	9.99991	**50**
4260	11	31495	5.31446	68505	31505	5.31436	68495	00009	99991	49
4320	12	32103	5.31446	67897	32112	5.31436	67888	00010	99990	48
4380	13	32702	5.31446	67298	32711	5.31436	67289	00010	99990	47
4440	14	33292	5.31446	66708	33302	5.31436	66698	00010	99990	46
4500	**15**	8.33875	5.31446	11.66125	8.33886	5.31436	11.66114	10.00010	9.99990	**45**
4560	16	34450	5.31446	65550	34461	5.31435	65539	00011	99989	44
4620	17	35018	5.31446	64982	35029	5.31435	64971	00011	99989	43
4680	18	35578	5.31446	64422	35590	5.31435	64410	00011	99989	42
4740	19	36131	5.31446	63869	36143	5.31435	63857	00011	99989	41
4800	**20**	8.36678	5.31446	11.63322	8.36689	5.31435	11.63311	10.00012	9.99988	**40**
4860	21	37217	5.31447	62783	37229	5.31434	62771	00012	99988	39
4920	22	37750	5.31447	62250	37762	5.31434	62238	00012	99988	38
4980	23	38276	5.31447	61724	38289	5.31434	61711	00013	99987	37
5040	24	38796	5.31447	61204	38809	5.31434	61191	00013	99987	36
5100	**25**	8.39310	5.31447	11.60690	8.39323	5.31434	11.60677	10.00013	9.99987	**35**
5160	26	39818	5.31447	60182	39832	5.31433	60168	00014	99986	34
5220	27	40320	5.31447	59680	40334	5.31433	59666	00014	99986	33
5280	28	40816	5.31447	59184	40830	5.31433	59170	00014	99986	32
5340	29	41307	5.31447	58693	41321	5.31433	58679	00015	99985	31
5400	**30**	8.41792	5.31447	11.58208	8.41807	5.31433	11.58193	10.00015	9.99985	**30**
5460	31	42272	5.31448	57728	42287	5.31432	57713	00015	99985	29
5520	32	42746	5.31448	57254	42762	5.31432	57238	00016	99984	28
5580	33	43216	5.31448	56784	43232	5.31432	56768	00016	99984	27
5640	34	43680	5.31448	56320	43696	5.31432	56304	00016	99984	26
5700	**35**	8.44139	5.31448	11.55861	8.44156	5.31431	11.55844	10.00017	9.99983	**25**
5760	36	44594	5.31448	55406	44611	5.31431	55389	00017	99983	24
5820	37	45044	5.31448	54956	45061	5.31431	54939	00017	99983	23
5880	38	45489	5.31448	54511	45507	5.31431	54493	00018	99982	22
5940	39	45930	5.31449	54070	45948	5.31431	54052	00018	99982	21
6000	**40**	8.46366	5.31449	11.53634	8.46385	5.31430	11.53615	10.00018	9.99982	**20**
6060	41	46799	5.31449	53201	46817	5.31430	53183	00019	99981	19
6120	42	47226	5.31449	52774	47245	5.31430	52755	00019	99981	18
6180	43	47650	5.31449	52350	47669	5.31430	52331	00019	99981	17
6240	44	48069	5.31449	51931	48089	5.31429	51911	00020	99980	16
6300	**45**	8.48485	5.31449	11.51515	8.48505	5.31429	11.51495	10.00020	9.99980	**15**
6360	46	48896	5.31449	51104	48917	5.31429	51083	00021	99979	14
6420	47	49304	5.31450	50696	49325	5.31428	50675	00021	99979	13
6480	48	49708	5.31450	50292	49729	5.31428	50271	00021	99979	12
6540	49	50108	5.31450	49892	50130	5.31428	49870	00022	99978	11
6600	**50**	8.50504	5.31450	11.49496	8.50527	5.31428	11.49473	10.00022	9.99978	**10**
6660	51	50897	5.31450	49103	50920	5.31427	49080	00023	99977	9
6720	52	51287	5.31450	48713	51310	5.31427	48690	00023	99977	8
6780	53	51673	5.31450	48327	51696	5.31427	48304	00023	99977	7
6840	54	52055	5.31450	47945	52079	5.31427	47921	00024	99976	6
6900	**55**	8.52434	5.31451	11.47566	8.52459	5.31426	11.47541	10.00024	9.99976	**5**
6960	56	52810	5.31451	47190	52835	5.31426	47165	00025	99975	4
7020	57	53183	5.31451	46817	53208	5.31426	46792	00025	99975	3
7080	58	53552	5.31451	46448	53578	5.31425	46422	00026	99974	2
7140	59	53919	5.31451	46081	53945	5.31425	46055	00026	99974	1
7200	**60**	54282	5.31451	45718	54308	5.31425	45692	00026	99974	**0**
	′	*l* cos		*l* sec	*l* cot		*l* tan	*l* csc	*l* sin	′

″	′	l sin	log S	l csc	l tan	log T	l cot	l sec	d 1′	l cos	′
7200	**0**	8.54282	5.31 451	11.45718	8.54308	5.31 425	11.45692	10.00026	1	9.99974	**60**
7260	1	54642	5.31 451	45358	54669	5.31 425	45331	00027	0	99973	59
7320	2	54999	5.31 452	45001	55027	5.31 424	44973	00027	1	99973	58
7380	3	55354	5.31 452	44646	55382	5.31 424	44618	00028	0	99972	57
7440	4	55705	5.31 452	44295	55734	5.31 424	44266	00028	1	99972	56
7500	**5**	8.56054	5.31 452	11.43946	8.56083	5.31 423	11.43917	10.00029	0	9.99971	**55**
7560	6	56400	5.31 452	43600	56429	5.31 423	43571	00029	1	99971	54
7620	7	56743	5.31 452	43257	56773	5.31 423	43227	00030	0	99970	53
7680	8	57084	5.31 453	42916	57114	5.31 422	42886	00030	1	99970	52
7740	9	57421	5.31 453	42579	57452	5.31 422	42548	00031	0	99969	51
7800	**10**	8.57757	5.31 453	11.42243	8.57788	5.31 422	11.42212	10.00031	1	9.99969	**50**
7860	11	58089	5.31 453	41911	58121	5.31 421	41879	00032	0	99968	49
7920	12	58419	5.31 453	41581	58451	5.31 421	41549	00032	1	99968	48
7980	13	58747	5.31 453	41253	58779	5.31 421	41221	00033	0	99967	47
8040	14	59072	5.31 454	40928	59105	5.31 421	40895	00033	0	99967	46
8100	**15**	8.59395	5.31 454	11.40605	8.59428	5.31 420	11.40572	10.00033	1	9.99967	**45**
8160	16	59715	5.31 454	40285	59749	5.31 420	40251	00034	0	99966	44
8220	17	60033	5.31 454	39967	60068	5.31 420	39932	00034	1	99966	43
8280	18	60349	5.31 454	39651	60384	5.31 419	39616	00035	1	99965	42
8340	19	60662	5.31 454	39338	60698	5.31 419	39302	00036	0	99964	41
8400	**20**	8.60973	5.31 455	11.39027	8.61009	5.31 418	11.38991	10.00036	1	9.99964	**40**
8460	21	61282	5.31 455	38718	61319	5.31 418	38681	00037	0	99963	39
8520	22	61589	5.31 455	38411	61626	5.31 418	38374	00037	1	99963	38
8580	23	61894	5.31 455	38106	61931	5.31 417	38069	00038	0	99962	37
8640	24	62196	5.31 455	37804	62234	5.31 417	37766	00038	1	99962	36
8700	**25**	8.62497	5.31 455	11.37503	8.62535	5.31 417	11.37465	10.00039	0	9.99961	**35**
8760	26	62795	5.31 456	37205	62834	5.31 416	37166	00039	1	99961	34
8820	27	63091	5.31 456	36909	63131	5.31 416	36869	00040	0	99960	33
8880	28	63385	5.31 456	36615	63426	5.31 416	36574	00040	1	99960	32
8940	29	63678	5.31 456	36322	63718	5.31 415	36282	00041	0	99959	31
9000	**30**	8.63968	5.31 456	11.36032	8.64009	5.31 415	11.35991	10.00041	1	9.99959	**30**
9060	31	64256	5.31 456	35744	64298	5.31 415	35702	00042	0	99958	29
9120	32	64543	5.31 457	35457	64585	5.31 414	35415	00042	1	99958	28
9180	33	64827	5.31 457	35173	64870	5.31 414	35130	00043	1	99957	27
9240	34	65110	5.31 457	34890	65154	5.31 413	34846	00044	0	99956	26
9300	**35**	8.65391	5.31 457	11.34609	8.65435	5.31 413	11.34565	10.00044	1	9.99956	**25**
9360	36	65670	5.31 457	34330	65715	5.31 413	34285	00045	0	99955	24
9420	37	65947	5.31 458	34053	65993	5.31 412	34007	00045	1	99955	23
9480	38	66223	5.31 458	33777	66269	5.31 412	33731	00046	0	99954	22
9540	39	66497	5.31 458	33503	66543	5.31 412	33457	00046	1	99954	21
9600	**40**	8.66769	5.31 458	11.33231	8.66816	5.31 411	11.33184	10.00047	1	9.99953	**20**
9660	41	67039	5.31 458	32961	67087	5.31 411	32913	00048	0	99952	19
9720	42	67308	5.31 459	32692	67356	5.31 410	32644	00048	1	99952	18
9780	43	67575	5.31 459	32425	67624	5.31 410	32376	00049	0	99951	17
9840	44	67841	5.31 459	32159	67890	5.31 410	32110	00049	1	99951	16
9900	**45**	8.68104	5.31 459	11.31896	8.68154	5.31 409	11.31846	10.00050	1	9.99950	**15**
9960	46	68367	5.31 459	31633	68417	5.31 409	31583	00051	0	99949	14
10020	47	68627	5.31 460	31373	68678	5.31 408	31322	00051	1	99949	13
10080	48	68886	5.31 460	31114	68938	5.31 408	31062	00052	0	99948	12
10140	49	69144	5.31 460	30856	69196	5.31 408	30804	00052	1	99948	11
10200	**50**	8.69400	5.31 460	11.30600	8.69453	5.31 407	11.30547	10.00053	1	9.99947	**10**
10260	51	69654	5.31 460	30346	69708	5.31 407	30292	00054	0	99946	9
10320	52	69907	5.31 461	30093	69962	5.31 406	30038	00054	1	99946	8
10380	53	70159	5.31 461	29841	70214	5.31 406	29786	00055	1	99945	7
10440	54	70409	5.31 461	29591	70465	5.31 405	29535	00056	0	99944	6
10500	**55**	8.70658	5.31 461	11.29342	8.70714	5.31 405	11.29286	10.00056	1	9.99944	**5**
10560	56	70905	5.31 461	29095	70962	5.31 405	29038	00057	1	99943	4
10620	57	71151	5.31 462	28849	71208	5.31 404	28792	00058	0	99942	3
10680	58	71395	5.31 462	28605	71453	5.31 404	28547	00058	1	99942	2
10740	59	71638	5.31 462	28362	71697	5.31 403	28303	00059	1	99941	1
10800	**60**	71880	5.31 462	28120	71940	5.31 403	28060	00060		99940	**0**
	′	l cos		l sec	l cot		l tan	l csc	d 1′	l sin	′

′	*l* sin 8.	d 1′	*l* csc 11.	*l* tan 8.	d 1′	*l* cot 11.	*l* sec 10.	d 1′	*l* cos 9.	′
0	71880	240	28120	71940	241	28060	00060	0	99940	60
1	72120	239	27880	72181	239	27819	060	1	940	59
2	359	238	641	420	239	580	061	1	939	58
3	597	237	403	659	237	341	062	0	938	57
4	834	235	166	896	236	104	062	1	938	56
5	73069	234	26931	73132	234	26868	063	1	937	55
6	303	232	697	366	234	634	064	0	936	54
7	535	232	465	600	232	400	064	1	936	53
8	767	230	233	832	231	168	065	1	935	52
9	997	229	003	74063	229	25937	066	0	934	51
10	74226	228	25774	292	229	708	066	1	934	50
11	454	226	546	521	227	479	067	1	933	49
12	680	226	320	748	226	252	068	0	932	48
13	906	224	094	974	225	026	068	1	932	47
14	75130	223	24870	75199	224	24801	069	1	931	46
15	353	222	647	423	222	577	070	1	930	45
16	575	220	425	645	222	355	071	0	929	44
17	795	220	205	867	220	133	071	1	929	43
18	76015	219	23985	76087	219	23913	072	1	928	42
19	234	217	766	306	219	694	073	1	927	41
20	451	216	549	525	217	475	074	0	926	40
21	667	216	333	742	216	258	074	1	926	39
22	883	214	117	958	215	042	075	1	925	38
23	77097	213	22903	77173	214	22827	076	1	924	37
24	310	212	690	387	213	613	077	0	923	36
25	522	211	478	600	211	400	077	1	923	35
26	733	210	267	811	211	189	078	1	922	34
27	943	209	057	78022	210	21978	079	1	921	33
28	78152	208	21848	232	209	768	080	0	920	32
29	360	208	640	441	208	559	080	1	920	31
30	78568	206	21432	78649	206	21351	00081	1	99919	30
31	774	205	226	855	206	145	082	1	918	29
32	979	204	021	79061	205	20939	083	0	917	28
33	79183	203	20817	266	204	734	083	1	917	27
34	386	202	614	470	203	530	084	1	916	26
35	588	201	412	673	202	327	085	1	915	25
36	789	201	211	875	201	125	086	1	914	24
37	990	199	010	80076	201	19924	087	0	913	23
38	80189	199	19811	277	199	723	087	1	913	22
39	388	197	612	476	198	524	088	1	912	21
40	585	197	415	674	198	326	089	1	911	20
41	782	196	218	872	196	128	090	1	910	19
42	978	195	022	81068	196	18932	091	0	909	18
43	81173	194	18827	264	195	736	091	1	909	17
44	367	193	633	459	194	541	092	1	908	16
45	560	192	440	653	193	347	093	1	907	15
46	752	192	248	846	192	154	094	1	906	14
47	944	190	056	82038	192	17962	095	1	905	13
48	82134	190	17866	230	190	770	096	0	904	12
49	324	189	676	420	190	580	096	1	904	11
50	513	188	487	610	189	390	097	1	903	10
51	701	187	299	799	188	201	098	1	902	9
52	888	187	112	987	188	013	099	1	901	8
53	83075	186	16925	83175	186	16825	100	1	900	7
54	261	185	739	361	186	639	101	1	899	6
55	446	184	554	547	185	453	102	0	898	5
56	630	183	370	732	184	268	102	1	898	4
57	813	183	187	916	184	084	103	1	897	3
58	996	181	004	84100	182	15900	104	1	896	2
59	84177	181	15823	282	182	718	105	1	895	1
60	84358		15642	84464		15536	00106		99894	0
′	8. *l* cos	d 1′	11. *l* sec	8. *l* cot	d 1′	11. *l* tan	10. *l* csc	d 1′	9. *l* sin	′

″	Proportional Parts 241	239	237	235	234	232	229
0	0	0	0	0	0	0	0
1	4	4	4	4	4	4	4
2	8	8	8	8	8	8	8
3	12	12	12	12	12	12	11
4	16	16	16	16	16	15	15
5	20	20	20	20	19	19	19
6	24	24	24	24	23	23	23
7	28	28	28	27	27	27	27
8	32	32	32	31	31	31	31
9	36	36	36	35	35	35	34
10	40	40	40	39	39	39	38
11	44	44	43	43	43	43	42
12	48	48	47	47	47	46	46
13	52	52	51	51	51	50	50
14	56	56	55	55	55	54	53
15	60	60	59	59	59	58	57
16	64	64	63	63	62	62	61
17	68	68	67	67	66	66	65
18	72	72	71	70	70	70	69
19	76	76	75	74	74	73	73
20	80	80	79	78	78	77	76
21	84	84	83	82	82	81	80
22	88	88	87	86	86	85	84
23	92	92	91	90	90	89	88
24	96	96	95	94	94	93	92
25	100	100	99	98	97	97	95
26	104	104	103	102	101	101	99
27	108	108	107	106	105	104	103
28	112	112	111	110	109	108	107
29	116	116	115	114	113	112	111
30	120	120	118	118	117	116	114
31	125	123	122	121	121	120	118
32	129	127	126	125	125	124	122
33	133	131	130	129	129	128	126
34	137	135	134	133	133	131	130
35	141	139	138	137	137	135	134
36	145	143	142	141	140	139	137
37	149	147	146	145	144	143	141
38	153	151	150	149	148	147	145
39	157	155	154	153	152	151	149
40	161	159	158	157	156	155	153
41	165	163	162	161	160	159	156
42	169	167	166	164	164	162	160
43	173	171	170	168	168	166	164
44	177	175	174	172	172	170	168
45	181	179	178	176	175	174	172
46	185	183	182	180	179	178	176
47	189	187	186	184	183	182	179
48	193	191	190	188	187	186	183
49	197	195	194	192	191	189	187
50	201	199	198	196	195	193	191
51	205	203	201	200	199	197	195
52	209	207	205	204	203	201	198
53	213	211	209	208	207	205	202
54	217	215	213	212	211	209	206
55	221	219	217	215	215	213	210
56	225	223	221	219	218	217	214
57	229	227	225	223	222	220	218
58	233	231	229	227	226	224	221
59	237	235	233	231	230	228	225
60	241	239	237	235	234	232	229
″	241 Proportional Parts	239	237	235	234	232	229

TABLE II

″	Proportional Parts																					
	227	**225**	**223**	**220**	**217**	**215**	**213**	**211**	**208**	**206**	**203**	**201**	**199**	**197**	**195**	**193**	**192**	**189**	**187**	**185**	**183**	**181**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3
2	8	8	7	7	7	7	7	7	7	7	7	7	7	7	6	6	6	6	6	6	6	6
3	11	11	11	11	11	11	11	11	10	10	10	10	10	10	10	10	10	9	9	9	9	9
4	15	15	15	15	14	14	14	14	14	14	14	13	13	13	13	13	13	13	12	12	12	12
5	19	19	19	18	18	18	18	18	17	17	17	17	17	16	16	16	16	16	16	15	15	15
6	23	22	22	22	22	22	21	21	21	21	20	20	20	20	20	19	19	19	19	18	18	18
7	26	26	26	26	25	25	25	25	24	24	24	23	23	23	23	23	22	22	22	22	21	21
8	30	30	30	29	29	29	28	28	28	27	27	27	27	26	26	26	26	25	25	25	24	24
9	34	34	33	33	33	32	32	32	31	31	30	30	30	30	29	29	29	28	28	28	27	27
10	38	38	37	37	36	36	36	35	35	34	34	34	33	33	32	32	32	32	31	31	30	30
11	42	41	41	40	40	39	39	39	38	38	37	37	36	36	36	35	35	35	34	34	34	33
12	45	45	45	44	43	43	43	42	42	41	41	40	40	39	39	39	38	38	37	37	37	36
13	49	49	48	48	47	47	46	46	45	45	44	44	43	43	42	42	42	41	41	40	40	39
14	53	52	52	51	51	50	50	49	49	48	47	47	46	46	46	45	45	44	44	43	43	42
15	57	56	56	55	54	54	53	53	52	51	51	50	50	49	49	48	48	47	47	46	46	45
16	61	60	59	59	58	57	57	56	55	55	54	54	53	53	52	51	51	50	50	49	49	48
17	64	64	63	62	61	61	60	60	59	58	58	57	56	56	55	55	54	54	53	52	52	51
18	68	68	67	66	65	64	64	63	62	62	61	60	60	59	58	58	58	57	56	56	55	54
19	72	71	71	70	69	68	67	67	66	65	64	64	63	62	62	61	61	60	59	59	58	57
20	76	75	74	73	72	72	71	70	69	69	68	67	66	66	65	64	64	63	62	62	61	60
21	79	79	78	77	76	75	75	74	73	72	71	70	70	69	68	68	67	66	65	65	64	63
22	83	82	82	81	80	79	78	77	76	76	74	74	73	72	72	71	70	69	69	68	67	66
23	87	86	85	84	83	82	82	81	80	79	78	77	76	76	75	74	74	72	72	71	70	69
24	91	90	89	88	87	86	85	84	83	82	81	80	80	79	78	77	77	76	75	74	73	72
25	95	94	93	92	90	90	89	88	87	86	85	84	83	82	81	80	80	79	78	77	76	75
26	98	98	97	95	94	93	92	91	90	89	88	87	86	85	84	84	83	82	81	80	79	78
27	102	101	100	99	98	97	96	95	94	93	91	90	90	89	88	87	86	85	84	83	82	81
28	106	105	104	103	101	100	99	98	97	96	95	94	93	92	91	90	90	88	87	86	85	84
29	110	109	108	106	105	104	103	102	101	100	98	97	96	95	94	93	93	91	90	89	88	87
30	114	112	112	110	108	108	106	106	104	103	102	100	100	98	98	96	96	94	94	92	92	90
31	117	116	115	114	112	111	110	109	107	106	105	104	103	102	101	100	99	98	97	96	95	94
32	121	120	119	117	116	115	114	113	111	110	108	107	106	105	104	103	102	101	100	99	98	97
33	125	124	123	121	119	118	117	116	114	113	112	111	109	108	107	106	106	104	103	102	101	100
34	129	128	126	125	123	122	121	120	118	117	115	114	113	112	110	109	109	107	106	105	104	103
35	132	131	130	128	127	125	124	123	121	120	118	117	116	115	114	113	112	110	109	108	107	106
36	136	135	134	132	130	129	128	127	125	124	122	121	119	118	117	116	115	113	112	111	110	109
37	140	139	138	136	134	133	131	130	128	127	125	124	123	121	120	119	118	117	115	114	113	112
38	144	142	141	139	137	136	135	134	132	130	129	127	126	125	124	122	122	120	118	117	116	115
39	148	146	145	143	141	140	138	137	135	134	132	131	129	128	127	125	125	123	122	120	119	118
40	151	150	149	147	145	143	142	141	139	137	135	134	133	131	130	129	128	126	125	123	122	121
41	155	154	152	150	148	147	146	144	142	141	139	137	136	135	133	132	131	129	128	126	125	124
42	159	158	156	154	152	150	149	148	146	144	142	141	139	138	136	135	134	132	131	130	128	127
43	163	161	160	158	156	154	153	151	149	148	145	144	143	141	140	138	138	135	134	133	131	130
44	166	165	164	161	159	158	156	155	153	151	149	147	146	144	143	142	141	139	137	136	134	133
45	170	169	167	165	163	161	160	158	156	155	152	151	149	148	146	145	144	142	140	139	137	136
46	174	172	171	169	166	165	163	162	159	158	156	154	153	151	150	148	147	145	143	142	140	139
47	178	176	175	172	170	168	167	165	163	161	159	157	156	154	153	151	150	148	146	145	143	142
48	182	180	178	176	174	172	170	169	166	165	162	161	159	158	156	154	154	151	150	148	146	145
49	185	184	182	180	177	176	174	172	170	168	166	164	163	161	159	158	157	154	153	151	149	148
50	189	188	186	183	181	179	178	176	173	172	169	168	166	164	162	161	160	158	156	154	152	151
51	193	191	190	187	184	183	181	179	177	175	173	171	169	167	166	164	163	161	159	157	156	154
52	197	195	193	191	188	186	185	183	180	179	176	174	172	171	169	167	166	164	162	160	159	157
53	201	199	197	194	192	190	188	186	184	182	179	178	176	174	172	170	170	167	165	163	162	160
54	204	202	201	198	195	194	192	190	187	185	183	181	179	177	176	174	173	170	168	166	165	163
55	208	206	204	202	199	197	195	193	191	189	186	184	182	181	179	177	176	173	171	170	168	166
56	212	210	208	205	203	201	199	197	194	192	189	188	186	184	182	180	179	176	175	173	171	169
57	216	214	212	209	206	204	202	200	198	196	193	191	189	187	185	183	182	180	178	176	174	172
58	219	218	216	213	210	208	206	204	201	199	196	194	192	190	188	187	186	183	181	179	177	175
59	223	221	219	216	213	211	209	207	205	203	200	198	196	194	192	190	189	186	184	182	180	178
60	227	225	223	220	217	215	213	211	208	206	203	201	199	197	195	193	192	189	187	185	183	181
″	**227**	**225**	**223**	**220**	**217**	**215**	**213**	**211**	**208**	**206**	**203**	**201**	**199**	**197**	**195**	**193**	**192**	**189**	**187**	**185**	**183**	**181**
	Proportional Parts																					

′	l sin 8.	d 1′	l csc 11.	l tan 8.	d 1′	l cot 11.	l sec 10.	d 1′	l cos 9.	′
0	84358	181	15642	84464	182	15536	00106	1	99894	60
1	539	179	461	646	180	354	107	1	893	59
2	718	179	282	826	180	174	108	1	892	58
3	897	178	103	85006	179	14994	109	0	891	57
4	85075	177	14925	185	178	815	109	1	891	56
5	252	177	748	363	177	637	110	1	890	55
6	429	176	571	540	177	460	111	1	889	54
7	605	175	395	717	176	283	112	1	888	53
8	780	175	220	893	176	107	113	1	887	52
9	955	173	045	86069	174	13931	114	1	886	51
10	86128	173	13872	243	174	757	115	1	885	50
11	301	173	699	417	174	583	116	1	884	49
12	474	171	526	591	172	409	117	1	883	48
13	645	171	355	763	172	237	118	1	882	47
14	816	171	184	935	171	065	119	1	881	46
15	987	169	013	87106	171	12894	120	1	880	45
16	87156	169	12844	277	170	723	121	0	879	44
17	325	169	675	447	169	553	121	1	879	43
18	494	167	506	616	169	384	122	1	878	42
19	661	168	339	785	168	215	123	1	877	41
20	829	166	171	953	167	047	124	1	876	40
21	995	166	005	88120	167	11880	125	1	875	39
22	88161	165	11839	287	166	713	126	1	874	38
23	326	164	674	453	165	547	127	1	873	37
24	490	164	510	618	165	382	128	1	872	36
25	654	163	346	783	165	217	129	1	871	35
26	817	163	183	948	163	052	130	1	870	34
27	980	162	020	89111	163	10889	131	1	869	33
28	89142	162	10858	274	163	726	132	1	868	32
29	304	160	696	437	161	563	133	1	867	31
30	89464	161	10536	89598	162	10402	00134	1	99866	30
31	625	159	375	760	160	240	135	1	865	29
32	784	159	216	920	160	080	136	1	864	28
33	943	159	057	90080	160	09920	137	1	863	27
34	90102	158	09898	240	159	760	138	1	862	26
35	260	157	740	399	158	601	139	1	861	25
36	417	157	583	557	158	443	140	1	860	24
37	574	156	426	715	157	285	141	1	859	23
38	730	155	270	872	157	128	142	1	858	22
39	885	155	115	91029	156	08971	143	1	857	21
40	91040	155	08960	185	155	815	144	1	856	20
41	195	154	805	340	155	660	145	1	855	19
42	349	153	651	495	155	505	146	1	854	18
43	502	153	498	650	153	350	147	1	853	17
44	655	152	345	803	154	197	148	1	852	16
45	807	152	193	957	153	043	149	1	851	15
46	959	151	041	92110	152	07890	150	2	850	14
47	92110	151	07890	262	152	738	152	1	848	13
48	261	150	739	414	151	586	153	1	847	12
49	411	150	589	565	151	435	154	1	846	11
50	561	149	439	716	150	284	155	1	845	10
51	710	149	290	866	150	134	156	1	844	9
52	859	148	141	93016	149	06984	157	1	843	8
53	93007	147	06993	165	148	835	158	1	842	7
54	154	147	846	313	149	687	159	1	841	6
55	301	147	699	462	147	538	160	1	840	5
56	448	146	552	609	147	391	161	1	839	4
57	594	146	406	756	147	244	162	1	838	3
58	740	145	260	903	146	097	163	1	837	2
59	885	145	115	94049	146	05951	164	2	836	1
60	94030		05970	94195		05805	00166		99834	0
′	8. l cos	d 1′	11. l sec	8. l cot	d 1′	11. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts 182	181	179	177	176	175	174
0	0	0	0	0	0	0	0
1	3	3	3	3	3	3	3
2	6	6	6	6	6	6	6
3	9	9	9	9	9	9	9
4	12	12	12	12	12	12	12
5	15	15	15	15	15	15	14
6	18	18	18	18	18	18	17
7	21	21	21	21	21	20	20
8	24	24	24	24	23	23	23
9	27	27	27	27	26	26	26
10	30	30	30	30	29	29	29
11	33	33	33	32	32	32	32
12	36	36	36	35	35	35	35
13	39	39	39	38	38	38	38
14	42	42	42	41	41	41	41
15	45	45	45	44	44	44	44
16	49	48	48	47	47	47	46
17	52	51	51	50	50	50	49
18	55	54	54	53	53	52	52
19	58	57	57	56	56	55	55
20	61	60	60	59	59	58	58
21	64	63	63	62	62	61	61
22	67	66	66	65	65	64	64
23	70	69	69	68	67	67	67
24	73	72	72	71	70	70	70
25	76	75	75	74	73	73	72
26	79	78	78	77	76	76	75
27	82	81	81	80	79	79	78
28	85	84	84	83	82	82	81
29	88	87	87	86	85	85	84
30	91	90	90	88	88	88	87
31	94	94	92	91	91	90	90
32	97	97	95	94	94	93	93
33	100	100	98	97	97	96	96
34	103	103	101	100	100	99	99
35	106	106	104	103	103	102	102
36	109	109	107	106	106	105	104
37	112	112	110	109	109	108	107
38	115	115	113	112	111	111	110
39	118	118	116	115	114	114	113
40	121	121	119	118	117	117	116
41	124	124	122	121	120	120	119
42	127	127	125	124	123	122	122
43	130	130	128	127	126	125	125
44	133	133	131	130	129	128	128
45	137	136	134	133	132	131	130
46	140	139	137	136	135	134	133
47	143	142	140	139	138	137	136
48	146	145	143	142	141	140	139
49	149	148	146	145	144	143	142
50	152	151	149	148	147	146	145
51	155	154	152	150	150	149	148
52	158	157	155	153	153	152	151
53	161	160	158	156	155	155	154
54	164	163	161	159	158	158	157
55	167	166	164	162	161	160	160
56	170	169	167	165	164	163	162
57	173	172	170	168	167	166	165
58	176	175	173	171	170	169	168
59	179	178	176	174	173	172	171
60	182	181	179	177	176	175	174
″	182 Proportional Parts	181	179	177	176	175	174

94° 85°

TABLE II

″	Proportional Parts																				
	173	**172**	**171**	**169**	**167**	**166**	**165**	**163**	**162**	**160**	**159**	**158**	**157**	**155**	**153**	**152**	**151**	**150**	**149**	**147**	**146**	**145**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2
2	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
3	9	9	9	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	7	7	7	7
4	12	11	11	11	11	11	11	11	11	11	11	11	10	10	10	10	10	10	10	10	10	10
5	14	14	14	14	14	14	14	14	14	13	13	13	13	13	13	13	13	12	12	12	12	12
6	17	17	17	17	17	17	16	16	16	16	16	16	16	16	15	15	15	15	15	15	15	14
7	20	20	20	20	19	19	19	19	19	19	19	18	18	18	18	18	18	18	17	17	17	17
8	23	23	23	23	22	22	22	22	22	21	21	21	21	21	20	20	20	20	20	20	19	19
9	26	26	26	25	25	25	25	24	24	24	24	24	24	23	23	23	23	22	22	22	22	22
10	29	29	28	28	28	28	28	27	27	27	26	26	26	26	26	25	25	25	25	24	24	24
11	32	32	31	31	31	30	30	30	30	29	29	29	29	28	28	28	28	28	27	27	27	27
12	35	34	34	34	33	33	33	33	32	32	32	32	31	31	31	30	30	30	30	29	29	29
13	37	37	37	37	36	36	36	35	35	35	34	34	34	34	33	33	33	32	32	32	32	31
14	40	40	40	39	39	39	38	38	38	37	37	37	37	36	36	35	35	35	35	34	34	34
15	43	43	43	42	42	42	41	41	40	40	40	40	39	39	38	38	38	38	37	37	36	36
16	46	46	46	45	45	44	44	43	43	43	42	42	42	41	41	41	40	40	40	39	39	39
17	49	49	48	48	47	47	47	46	46	45	45	45	44	44	43	43	43	42	42	42	41	41
18	52	52	51	51	50	50	50	49	49	48	48	47	47	46	46	46	45	45	45	44	44	44
19	55	54	54	54	53	53	52	52	51	51	50	50	50	49	48	48	48	48	47	47	46	46
20	58	57	57	56	56	55	55	54	54	53	53	53	52	52	51	51	50	50	50	49	49	48
21	61	60	60	59	58	58	58	57	57	56	56	55	55	54	54	53	53	52	52	51	51	51
22	63	63	63	62	61	61	60	60	59	59	58	58	58	57	56	56	55	55	55	54	54	53
23	66	66	66	65	64	64	63	62	62	61	61	61	60	59	59	58	58	58	57	56	56	56
24	69	69	68	68	67	66	66	65	65	64	64	63	63	62	61	61	60	60	60	59	58	58
25	72	72	71	70	70	69	69	68	68	67	66	66	65	65	64	63	63	62	62	61	61	60
26	75	75	74	73	72	72	72	71	70	69	69	68	68	67	66	66	65	65	65	64	63	63
27	78	77	77	76	75	75	74	73	73	72	72	71	71	70	69	68	68	68	67	66	66	65
28	81	80	80	79	78	77	77	76	76	75	74	74	73	72	71	71	70	70	70	69	68	68
29	84	83	83	82	81	80	80	79	78	77	77	76	76	75	74	73	73	72	72	71	71	70
30	86	86	86	84	84	83	82	82	81	80	80	79	78	78	76	76	76	75	74	74	73	72
31	89	89	88	87	86	86	85	84	84	83	82	82	81	80	79	79	78	78	77	76	75	75
32	92	92	91	90	89	89	88	87	86	85	85	84	84	83	82	81	81	80	79	78	78	77
33	95	95	94	93	92	91	91	90	89	88	87	87	86	85	84	84	83	82	82	81	80	80
34	98	97	97	96	95	94	94	92	92	91	90	90	89	88	87	86	86	85	84	83	83	82
35	101	100	100	99	97	97	96	95	94	93	93	92	92	90	89	89	88	88	87	86	85	85
36	104	103	103	101	100	100	99	98	97	96	95	95	94	93	92	91	91	90	89	88	88	87
37	107	106	105	104	103	102	102	101	100	99	98	97	97	96	94	94	93	92	92	91	90	89
38	110	109	108	107	106	105	104	103	103	101	101	100	99	98	97	96	96	95	94	93	92	92
39	112	112	111	110	109	108	107	106	105	104	103	103	102	101	99	99	98	98	97	96	95	94
40	115	115	114	113	111	111	110	109	108	107	106	105	105	103	102	101	101	100	99	98	97	97
41	118	118	117	115	114	113	113	111	111	109	109	108	107	106	105	104	103	102	102	100	100	99
42	121	120	120	118	117	116	116	114	113	112	111	111	110	108	107	106	106	105	104	103	102	102
43	124	123	123	121	120	119	118	117	116	115	114	113	113	111	110	109	108	108	107	105	105	104
44	127	126	125	124	122	122	121	120	119	117	117	116	115	114	112	111	111	110	109	108	107	106
45	130	129	128	127	125	124	124	122	122	120	119	118	118	116	115	114	113	112	112	110	110	109
46	133	132	131	130	128	127	126	125	124	123	122	121	120	119	117	117	116	115	114	113	112	111
47	136	135	134	132	131	130	129	128	127	125	125	124	123	121	120	119	118	118	117	115	114	114
48	138	138	137	135	134	133	132	130	130	128	127	126	126	124	122	122	121	120	119	118	117	116
49	141	140	140	138	136	136	135	133	132	131	130	129	128	127	125	124	123	122	122	120	119	118
50	144	143	142	141	139	138	138	136	135	133	132	132	131	129	128	127	126	125	124	122	122	121
51	147	146	145	144	142	141	140	139	138	136	135	134	133	132	130	129	128	128	127	125	124	123
52	150	149	148	146	145	144	143	141	140	139	138	137	136	134	133	132	131	130	129	127	127	126
53	153	152	151	149	148	147	146	144	143	141	140	140	139	137	135	134	133	132	132	130	129	128
54	156	155	154	152	150	149	148	147	146	144	143	142	141	140	138	137	136	135	134	132	131	130
55	159	158	157	155	153	152	151	149	148	147	146	145	144	142	140	139	138	138	137	135	134	133
56	161	161	160	158	156	155	154	152	151	149	148	147	147	145	143	142	141	140	139	137	136	135
57	164	163	162	161	159	158	157	155	154	152	151	150	149	147	145	144	143	142	142	140	139	138
58	167	166	165	163	161	160	160	158	157	155	154	153	152	150	148	147	146	145	144	142	141	140
59	170	169	168	166	164	163	162	160	159	157	156	155	154	152	150	149	148	148	147	145	144	143
60	173	172	171	169	167	166	165	163	162	160	159	158	157	155	153	152	151	150	149	147	146	145
″	**173**	**172**	**171**	**169**	**167**	**166**	**165**	**163**	**162**	**160**	**159**	**158**	**157**	**155**	**153**	**152**	**151**	**150**	**149**	**147**	**146**	**145**
	Proportional Parts																					

′	l sin 8.	d 1′	l csc 11.	l tan 8.	d 1′	l cot 11.	l sec 10.	d 1′	l cos 9.	′
0	94030	144	05970	94195	145	05805	00166	1	99834	60
1	174	143	826	340	145	660	167	1	833	59
2	317	144	683	485	145	515	168	1	832	58
3	461	142	539	630	143	370	169	1	831	57
4	603	143	397	773	144	227	170	1	830	56
5	746	141	254	917	143	083	171	1	829	55
6	887	142	113	95060	142	04940	172	1	828	54
7	95029	141	04971	202	142	798	173	2	827	53
8	170	140	830	344	142	656	175	1	825	52
9	310	140	690	486	141	514	176	1	824	51
10	450	139	550	627	140	373	177	1	823	50
11	589	139	411	767	141	233	178	1	822	49
12	728	139	272	908	139	092	179	1	821	48
13	867	138	133	96047	140	03953	180	1	820	47
14	96005	138	03995	187	138	813	181	2	819	46
15	143	137	857	325	139	675	183	1	817	45
16	280	137	720	464	138	536	184	1	816	44
17	417	136	583	602	137	398	185	1	815	43
18	553	136	447	739	138	261	186	1	814	42
19	689	136	311	877	136	123	187	1	813	41
20	825	135	175	97013	137	02987	188	2	812	40
21	960	135	040	150	135	850	190	1	810	39
22	97095	134	02905	285	136	715	191	1	809	38
23	229	134	771	421	135	579	192	1	808	37
24	363	133	637	556	135	444	193	1	807	36
25	496	133	504	691	134	309	194	2	806	35
26	629	133	371	825	134	175	196	1	804	34
27	762	132	238	959	133	041	197	1	803	33
28	894	132	106	98092	133	01908	198	1	802	32
29	98026	131	01974	225	133	775	199	1	801	31
30	98157	131	01843	98358	132	01642	00200	2	99800	30
31	288	131	712	490	132	510	202	1	798	29
32	419	130	581	622	131	378	203	1	797	28
33	549	130	451	753	131	247	204	1	796	27
34	679	129	321	884	131	116	205	2	795	26
35	808	129	192	99015	130	00985	207	1	793	25
36	937	129	063	145	130	855	208	1	792	24
37	99066	128	00934	275	130	725	209	1	791	23
38	194	128	806	405	129	595	210	2	790	22
39	322	128	678	534	128	466	212	1	788	21
40	450	127	550	662	129	338	213	1	787	20
41	577	127	423	791	128	209	214	1	786	19
42	704	126	296	919	127	081	215	2	785	18
43	830	126	170	00046	128	99954	217	1	783	17
44	956	126	044	174	127	826	218	1	782	16
45	00082	125	99918	301	126	699	219	1	781	15
46	207	125	793	427	126	573	220	2	780	14
47	332	124	668	553	126	447	222	1	778	13
48	456	125	544	679	126	321	223	1	777	12
49	581	123	419	805	125	195	224	1	776	11
50	704	124	296	930	125	070	225	2	775	10
51	828	123	172	01055	124	98945	227	1	773	9
52	951	123	049	179	124	821	228	1	772	8
53	01074	122	98926	303	124	697	229	2	771	7
54	196	122	804	427	123	573	231	1	769	6
55	318	122	682	550	123	450	232	1	768	5
56	440	121	560	673	123	327	233	2	767	4
57	561	121	439	796	122	204	235	1	765	3
58	682	121	318	918	122	082	236	1	764	2
59	803	120	197	02040	122	97960	237	2	763	1
60	01923		98077	02162		97838	00239		99761	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts						
	145	144	143	142	141	140	139
0	0	0	0	0	0	0	0
1	2	2	2	2	2	2	2
2	5	5	5	5	5	5	5
3	7	7	7	7	7	7	7
4	10	10	10	9	9	9	9
5	12	12	12	12	12	12	12
6	14	14	14	14	14	14	14
7	17	17	17	17	16	16	16
8	19	19	19	19	19	19	19
9	22	22	21	21	21	21	21
10	24	24	24	24	24	23	23
11	27	26	26	26	26	26	25
12	29	29	29	28	28	28	28
13	31	31	31	31	31	30	30
14	34	34	33	33	33	33	32
15	36	36	36	36	35	35	35
16	39	38	38	38	38	37	37
17	41	41	41	40	40	40	39
18	44	43	43	43	42	42	42
19	46	46	45	45	45	44	44
20	48	48	48	47	47	47	46
21	51	50	50	50	49	49	49
22	53	53	52	52	52	51	51
23	56	55	55	54	54	54	53
24	58	58	57	57	56	56	56
25	60	60	60	59	59	58	58
26	63	62	62	62	61	61	60
27	65	65	64	64	63	63	63
28	68	67	67	66	66	65	65
29	70	70	69	69	68	68	67
30	72	72	72	71	70	70	70
31	75	74	74	73	73	72	72
32	77	77	76	76	75	75	74
33	80	79	79	78	78	77	76
34	82	82	81	80	80	79	79
35	85	84	83	83	82	82	81
36	87	86	86	85	85	84	83
37	89	89	88	88	87	86	86
38	92	91	91	90	89	89	88
39	94	94	93	92	92	91	90
40	97	96	95	95	94	93	93
41	99	98	98	97	96	96	95
42	102	101	100	99	99	98	97
43	104	103	102	102	101	100	100
44	106	106	105	104	103	103	102
45	109	108	107	106	106	105	104
46	111	110	110	109	108	107	107
47	114	113	112	111	110	110	109
48	116	115	114	114	113	112	111
49	118	118	117	116	115	114	114
50	121	120	119	118	118	117	116
51	123	122	122	121	120	119	118
52	126	125	124	123	122	121	120
53	128	127	126	125	125	124	123
54	130	130	129	128	127	126	125
55	133	132	131	130	129	128	127
56	135	134	133	133	132	131	130
57	138	137	136	135	134	133	132
58	140	139	138	137	136	135	134
59	143	142	141	140	139	138	137
60	145	144	143	142	141	140	139
″	145	144	143	142	141	140	139
	Proportional Parts						

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TABLE II

″	138	137	136	135	134	133	132	131	130	129	128	127	126	125	124	123	122	121	120	2	1
	Proportional Parts																				
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	0
2	5	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0
3	7	7	7	7	7	7	7	7	6	6	6	6	6	6	6	6	6	6	6	0	0
4	9	9	9	9	9	9	9	9	9	9	9	8	8	8	8	8	8	8	8	0	0
5	12	11	11	11	11	11	11	11	11	11	11	11	10	10	10	10	10	10	10	0	0
6	14	14	14	14	13	13	13	13	13	13	13	13	13	12	12	12	12	12	12	0	0
7	16	16	16	16	16	16	15	15	15	15	15	15	15	15	14	14	14	14	14	0	0
8	18	18	18	18	18	18	18	17	17	17	17	17	17	17	17	16	16	16	16	0	0
9	21	21	20	20	20	20	20	20	20	19	19	19	19	19	19	18	18	18	18	0	0
10	23	23	23	22	22	22	22	22	22	22	21	21	21	21	21	20	20	20	20	0	0
11	25	25	25	25	25	24	24	24	24	24	23	23	23	23	23	23	22	22	22	0	0
12	28	27	27	27	27	27	26	26	26	26	26	25	25	25	25	25	24	24	24	0	0
13	30	30	29	29	29	29	29	28	28	28	28	28	27	27	27	27	26	26	26	0	0
14	32	32	32	32	31	31	31	31	30	30	30	30	29	29	29	29	28	28	28	0	0
15	34	34	34	34	34	33	33	33	32	32	32	32	32	31	31	31	30	30	30	0	0
16	37	37	36	36	36	35	35	35	35	34	34	34	34	33	33	33	33	32	32	1	0
17	39	39	39	38	38	38	37	37	37	37	36	36	36	35	35	35	35	34	34	1	0
18	41	41	41	40	40	40	40	39	39	39	38	38	38	38	37	37	37	36	36	1	0
19	44	43	43	43	42	42	42	41	41	41	41	40	40	40	39	39	39	38	38	1	0
20	46	46	45	45	45	44	44	44	43	43	43	42	42	42	41	41	41	40	40	1	0
21	48	48	48	47	47	47	46	46	46	45	45	44	44	44	43	43	43	42	42	1	0
22	51	50	50	50	49	49	48	48	48	47	47	47	46	46	45	45	45	44	44	1	0
23	53	53	52	52	51	51	51	50	50	49	49	49	48	48	48	47	47	46	46	1	0
24	55	55	54	54	54	53	53	52	52	52	51	51	50	50	50	49	49	48	48	1	0
25	58	57	57	56	56	55	55	55	54	54	53	53	52	52	52	51	51	50	50	1	0
26	60	59	59	58	58	58	57	57	56	56	55	55	55	54	54	53	53	52	52	1	0
27	62	62	61	61	60	60	59	59	58	58	58	57	57	56	56	55	55	54	54	1	0
28	64	64	63	63	63	62	62	61	61	60	60	59	59	58	58	57	57	56	56	1	0
29	67	66	66	65	65	64	64	63	63	62	62	61	61	60	60	59	59	58	58	1	0
30	69	68	68	68	67	66	66	66	65	64	64	64	63	62	62	62	61	60	60	1	0
31	71	71	70	70	69	69	68	68	67	67	66	66	65	65	64	64	63	63	62	1	1
32	74	73	73	72	71	71	70	70	69	69	68	68	67	67	66	66	65	65	64	1	1
33	76	75	75	74	74	73	73	72	72	71	70	70	69	69	68	68	67	67	66	1	1
34	78	78	77	76	76	75	75	74	74	73	73	72	71	71	70	70	69	69	68	1	1
35	80	80	79	79	78	78	77	76	76	75	75	74	74	73	72	72	71	71	70	1	1
36	83	82	82	81	80	80	79	79	78	77	77	76	76	75	74	74	73	73	72	1	1
37	85	84	84	83	83	82	81	81	80	80	79	78	78	77	76	76	75	75	74	1	1
38	87	87	86	86	85	84	84	83	82	82	81	80	80	79	79	78	77	77	76	1	1
39	90	89	88	88	87	86	86	85	84	84	83	83	82	81	81	80	79	79	78	1	1
40	92	91	91	90	89	89	88	87	87	86	85	85	84	83	83	82	81	81	80	1	1
41	94	94	93	92	92	91	90	90	89	88	87	87	86	85	85	84	83	83	82	1	1
42	97	96	95	94	94	93	92	92	91	90	90	89	88	88	87	86	85	85	84	1	1
43	99	98	97	97	96	95	95	94	93	92	92	91	90	90	89	88	87	87	86	1	1
44	101	100	100	99	98	98	97	96	95	95	94	93	92	92	91	90	89	89	88	1	1
45	104	103	102	101	100	100	99	98	98	97	96	95	94	94	93	92	92	91	90	2	1
46	106	105	104	104	103	102	101	100	100	99	98	97	97	96	95	94	94	93	92	2	1
47	108	107	107	106	105	104	103	103	102	101	100	99	99	98	97	96	96	95	94	2	1
48	110	110	109	108	107	106	106	105	104	103	102	102	101	100	99	98	98	97	96	2	1
49	113	112	111	110	109	109	108	107	106	105	105	104	103	102	101	100	100	99	98	2	1
50	115	114	113	112	112	111	110	109	108	108	107	106	105	104	103	102	102	101	100	2	1
51	117	116	116	115	114	113	112	111	110	110	109	108	107	106	105	105	104	103	102	2	1
52	120	119	118	117	116	115	114	114	113	112	111	110	109	108	107	107	106	105	104	2	1
53	122	121	120	119	118	117	117	116	115	114	113	112	111	110	110	109	108	107	106	2	1
54	124	123	122	122	121	120	119	118	117	116	115	114	113	112	112	111	110	109	108	2	1
55	126	126	125	124	123	122	121	120	119	118	117	116	116	115	114	113	112	111	110	2	1
56	129	128	127	126	125	124	123	122	121	120	119	119	118	117	116	115	114	113	112	2	1
57	131	130	129	128	127	126	125	124	124	123	122	121	120	119	118	117	116	115	114	2	1
58	133	132	131	130	130	129	128	127	126	125	124	123	122	121	120	119	118	117	116	2	1
59	136	135	134	133	132	131	130	129	128	127	126	125	124	123	122	121	120	119	118	2	1
60	138	137	136	135	134	133	132	131	130	129	128	127	126	125	124	123	122	121	120	2	1
″	**138**	**137**	**136**	**135**	**134**	**133**	**132**	**131**	**130**	**129**	**128**	**127**	**126**	**125**	**124**	**123**	**122**	**121**	**120**	**2**	**1**
	Proportional Parts																				

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	01923	120	98077	02162	121	97838	00239	1	99761	60
1	02043	120	97957	283	121	717	240	1	760	59
2	163	120	837	404	121	596	241	2	759	58
3	283	119	717	525	120	475	243	1	757	57
4	402	118	598	645	121	355	244	1	756	56
5	520	119	480	766	119	234	245	2	755	55
6	639	118	361	885	120	115	247	1	753	54
7	757	117	243	03005	119	96995	248	1	752	53
8	874	118	126	124	118	876	249	2	751	52
9	992	117	008	242	119	758	251	1	749	51
10	03109	117	96891	361	118	639	252	1	748	50
11	226	116	774	479	118	521	253	2	747	49
12	342	116	658	597	117	403	255	1	745	48
13	458	116	542	714	118	286	256	2	744	47
14	574	116	426	832	116	168	258	1	742	46
15	690	115	310	948	117	052	259	1	741	45
16	805	115	195	04065	116	95935	260	2	740	44
17	920	114	080	181	116	819	262	1	738	43
18	04034	115	95966	297	116	703	263	1	737	42
19	149	113	851	413	115	587	264	2	736	41
20	262	114	738	528	115	472	266	1	734	40
21	376	114	624	643	115	357	267	2	733	39
22	490	113	510	758	115	242	269	1	731	38
23	603	112	397	873	114	127	270	2	730	37
24	715	113	285	987	114	013	272	1	728	36
25	828	112	172	05101	113	94899	273	1	727	35
26	940	112	060	214	114	786	274	2	726	34
27	05052	112	94948	328	113	672	276	1	724	33
28	164	111	836	441	112	559	277	2	723	32
29	275	111	725	553	113	447	279	1	721	31
30	05386	111	94614	05666	112	94334	00280	2	99720	30
31	497	110	503	778	112	222	282	1	718	29
32	607	110	393	890	112	110	283	1	717	28
33	717	110	283	06002	111	93998	284	2	716	27
34	827	110	173	113	111	887	286	1	714	26
35	937	109	063	224	111	776	287	2	713	25
36	06046	109	93954	335	110	665	289	1	711	24
37	155	109	845	445	111	555	290	2	710	23
38	264	108	736	556	110	444	292	1	708	22
39	372	109	628	666	109	334	293	2	707	21
40	481	108	519	775	110	225	295	1	705	20
41	589	107	411	885	109	115	296	2	704	19
42	696	108	304	994	109	006	298	1	702	18
43	804	107	196	07103	108	92897	299	2	701	17
44	911	107	089	211	109	789	301	1	699	16
45	07018	106	92982	320	108	680	302	2	698	15
46	124	107	876	428	108	572	304	1	696	14
47	231	106	769	536	107	464	305	2	695	13
48	337	105	663	643	108	357	307	1	693	12
49	442	106	558	751	107	249	308	2	692	11
50	548	105	452	858	106	142	310	1	690	10
51	653	105	347	964	107	036	311	2	689	9
52	758	105	242	08071	106	91929	313	1	687	8
53	863	105	137	177	106	823	314	2	686	7
54	968	104	032	283	106	717	316	1	684	6
55	08072	104	91928	389	106	611	317	2	683	5
56	176	104	824	495	105	505	319	1	681	4
57	280	103	720	600	105	400	320	2	680	3
58	383	103	617	705	105	295	322	1	678	2
59	486	103	514	810	104	190	323	2	677	1
60	08589		91411	08914		91086	00325		99675	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts 121	120	119	118	117
0	0	0	0	0	0
1	2	2	2	2	2
2	4	4	4	4	4
3	6	6	6	6	6
4	8	8	8	8	8
5	10	10	10	10	10
6	12	12	12	12	12
7	14	14	14	14	14
8	16	16	16	16	16
9	18	18	18	18	18
10	20	20	20	20	20
11	22	22	22	22	21
12	24	24	24	24	23
13	26	26	26	26	25
14	28	28	28	28	27
15	30	30	30	29	29
16	32	32	32	31	31
17	34	34	34	33	33
18	36	36	36	35	35
19	38	38	38	37	37
20	40	40	40	39	39
21	42	42	42	41	41
22	44	44	44	43	43
23	46	46	46	45	45
24	48	48	48	47	47
25	50	50	50	49	49
26	52	52	52	51	51
27	54	54	54	53	53
28	56	56	56	55	55
29	58	58	58	57	57
30	60	60	60	59	58
31	63	62	61	61	60
32	65	64	63	63	62
33	67	66	65	65	64
34	69	68	67	67	66
35	71	70	69	69	68
36	73	72	71	71	70
37	75	74	73	73	72
38	77	76	75	75	74
39	79	78	77	77	76
40	81	80	79	79	78
41	83	82	81	81	80
42	85	84	83	83	82
43	87	86	85	85	84
44	89	88	87	87	86
45	91	90	89	89	88
46	93	92	91	90	90
47	95	94	93	92	92
48	97	96	95	94	94
49	99	98	97	96	96
50	101	100	99	98	98
51	103	102	101	100	99
52	105	104	103	102	101
53	107	106	105	104	103
54	109	108	107	106	105
55	111	110	109	108	107
56	113	112	111	110	109
57	115	114	113	112	111
58	117	116	115	114	113
59	119	118	117	116	115
60	121	120	119	118	117
″	121 Proportional Parts	120	119	118	117

96° 83°

TABLE II

"	Proportional Parts													
	116	**115**	**114**	**113**	**112**	**111**	**110**	**109**	**108**	**107**	**106**	**105**	**104**	**2**	**1**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	2	2	2	2	2	2	2	2	2	2	2	2	0	0
2	4	4	4	4	4	4	4	4	4	4	4	4	3	0	0
3	6	6	6	6	6	6	5	5	5	5	5	5	5	0	0
4	8	8	8	8	7	7	7	7	7	7	7	7	7	0	0
5	10	10	9	9	9	9	9	9	9	9	9	9	9	0	0
6	12	12	11	11	11	11	11	11	11	11	11	10	10	0	0
7	14	13	13	13	13	13	13	13	13	12	12	12	12	0	0
8	15	15	15	15	15	15	15	15	14	14	14	14	14	0	0
9	17	17	17	17	17	17	17	16	16	16	16	16	16	0	0
10	19	19	19	19	19	18	18	18	18	18	18	18	17	0	0
11	21	21	21	21	21	20	20	20	20	20	19	19	19	0	0
12	23	23	23	23	22	22	22	22	22	21	21	21	21	0	0
13	25	25	25	24	24	24	24	24	23	23	23	23	23	0	0
14	27	27	27	26	26	26	26	25	25	25	25	24	24	0	0
15	29	29	29	28	28	28	27	27	27	27	27	26	26	0	0
16	31	31	30	30	30	30	29	29	29	29	28	28	28	1	0
17	33	33	32	32	32	31	31	31	31	30	30	30	29	1	0
18	35	34	34	34	34	33	33	33	32	32	32	32	31	1	0
19	37	36	36	36	35	35	35	35	34	34	34	33	33	1	0
20	39	38	38	38	37	37	37	36	36	36	35	35	35	1	0
21	41	40	40	40	39	39	39	38	38	37	37	37	36	1	0
22	43	42	42	41	41	41	40	40	40	39	39	38	38	1	0
23	44	44	44	43	43	43	42	42	41	41	41	40	40	1	0
24	46	46	46	45	45	44	44	44	43	43	42	42	42	1	0
25	48	48	47	47	47	46	46	45	45	45	44	44	43	1	0
26	50	50	49	49	49	48	48	47	47	46	46	46	45	1	0
27	52	52	51	51	50	50	49	49	49	48	48	47	47	1	0
28	54	54	53	53	52	52	51	51	50	50	49	49	49	1	0
29	56	56	55	55	54	54	53	53	52	52	51	51	50	1	0
30	58	58	57	56	56	56	55	54	54	54	53	52	52	1	0
31	60	59	59	58	58	57	57	56	56	55	55	54	54	1	1
32	62	61	61	60	60	59	59	58	58	57	57	56	55	1	1
33	64	63	63	62	62	61	61	60	59	59	58	58	57	1	1
34	66	65	65	64	63	63	62	62	61	61	60	60	59	1	1
35	68	67	67	66	65	65	64	64	63	62	62	61	61	1	1
36	70	69	68	68	67	67	66	65	65	64	64	63	62	1	1
37	72	71	70	70	69	68	68	67	67	66	65	65	64	1	1
38	73	73	72	72	71	70	70	69	68	68	67	66	66	1	1
39	75	75	74	73	73	72	72	71	70	70	69	68	68	1	1
40	77	77	76	75	75	74	73	73	72	71	71	70	69	1	1
41	79	79	78	77	77	76	75	74	74	73	72	72	71	1	1
42	81	80	80	79	78	78	77	76	76	75	74	74	73	1	1
43	83	82	82	81	80	80	79	78	77	77	76	75	75	1	1
44	85	84	84	83	82	81	81	80	79	78	78	77	76	1	1
45	87	86	85	85	84	83	83	82	81	80	79	79	78	2	1
46	89	88	87	87	86	85	84	84	83	82	81	80	80	2	1
47	91	90	89	89	88	87	86	85	85	84	83	82	81	2	1
48	93	92	91	90	90	89	88	87	86	86	85	84	83	2	1
49	95	94	93	92	91	91	90	89	88	87	87	86	85	2	1
50	97	96	95	94	93	92	92	91	90	89	88	88	87	2	1
51	99	98	97	96	95	94	93	93	92	91	90	89	88	2	1
52	101	100	99	98	97	96	95	94	94	93	92	91	90	2	1
53	102	102	101	100	99	98	97	96	95	95	94	93	92	2	1
54	104	104	103	102	101	100	99	98	97	96	95	94	94	2	1
55	106	105	105	104	103	102	101	100	99	98	97	96	95	2	1
56	108	107	106	105	105	104	103	102	101	100	99	98	97	2	1
57	110	109	108	107	106	105	105	104	103	102	101	100	99	2	1
58	112	111	110	109	108	107	106	105	104	103	102	102	101	2	1
59	114	113	112	111	110	109	108	107	106	105	104	103	102	2	1
60	116	115	114	113	112	111	110	109	108	107	106	105	104	2	1
"	**116**	**115**	**114**	**113**	**112**	**111**	**110**	**109**	**108**	**107**	**106**	**105**	**104**	**2**	**1**
	Proportional Parts														

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	08589	103	91411	08914	105	91086	00325	1	99675	60
1	692	103	308	09019	104	90981	326	2	674	59
2	795	102	205	123	104	877	328	2	672	58
3	897	102	103	227	103	773	330	1	670	57
4	999	102	001	330	104	670	331	2	669	56
5	09101	101	90899	434	103	566	333	1	667	55
6	202	102	798	537	103	463	334	2	666	54
7	304	101	696	640	102	360	336	1	664	53
8	405	101	595	742	103	258	337	2	663	52
9	506	100	494	845	102	155	339	2	661	51
10	606	101	394	947	102	053	341	1	659	50
11	707	100	293	10049	101	89951	342	2	658	49
12	807	100	193	150	102	850	344	1	656	48
13	907	99	093	252	101	748	345	2	655	47
14	10006	100	89994	353	101	647	347	2	653	46
15	106	99	894	454	101	546	349	1	651	45
16	205	99	795	555	101	445	350	2	650	44
17	304	98	696	656	100	344	352	1	648	43
18	402	99	598	756	100	244	353	2	647	42
19	501	98	499	856	100	144	355	2	645	41
20	599	98	401	956	100	044	357	1	643	40
21	697	98	303	11056	99	88944	358	2	642	39
22	795	98	205	155	99	845	360	2	640	38
23	893	97	107	254	99	746	362	1	638	37
24	990	97	010	353	99	647	363	2	637	36
25	11087	97	88913	452	99	548	365	2	635	35
26	184	97	816	551	98	449	367	1	633	34
27	281	96	719	649	98	351	368	2	632	33
28	377	97	623	747	98	253	370	1	630	32
29	474	96	526	845	98	155	371	2	629	31
30	11570	96	88430	11943	97	88057	00373	2	99627	30
31	666	95	334	12040	98	87960	375	1	625	29
32	761	96	239	138	97	862	376	2	624	28
33	857	95	143	235	97	765	378	2	622	27
34	952	95	048	332	96	668	380	2	620	26
35	12047	95	87953	428	97	572	382	1	618	25
36	142	94	858	525	96	475	383	2	617	24
37	236	95	764	621	96	379	385	2	615	23
38	331	94	669	717	96	283	387	1	613	22
39	425	94	575	813	96	187	388	2	612	21
40	519	93	481	909	95	091	390	2	610	20
41	612	94	388	13004	95	86996	392	1	608	19
42	706	93	294	099	95	901	393	2	607	18
43	799	93	201	194	95	806	395	2	605	17
44	892	93	108	289	95	711	397	2	603	16
45	985	93	015	384	94	616	399	1	601	15
46	13078	93	86922	478	95	522	400	2	600	14
47	171	92	829	573	94	427	402	2	598	13
48	263	92	737	667	94	333	404	1	596	12
49	355	92	645	761	93	239	405	2	595	11
50	447	92	553	854	94	146	407	2	593	10
51	539	91	461	948	93	052	409	2	591	9
52	630	92	370	14041	93	85959	411	1	589	8
53	722	91	278	134	93	866	412	2	588	7
54	813	91	187	227	93	773	414	2	586	6
55	904	90	096	320	92	680	416	2	584	5
56	994	91	006	412	92	588	418	1	582	4
57	14085	90	85915	504	93	496	419	2	581	3
58	175	91	825	597	91	403	421	2	579	2
59	266	90	734	688	92	312	423	2	577	1
60	14356		85644	14780		85220	00425		99575	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts 105	104	103	102
0	0	0	0	0
1	2	2	2	2
2	4	3	3	3
3	5	5	5	5
4	7	7	7	7
5	9	9	9	9
6	10	10	10	10
7	12	12	12	12
8	14	14	14	14
9	16	16	15	15
10	18	17	17	17
11	19	19	19	19
12	21	21	21	20
13	23	23	22	22
14	24	24	24	24
15	26	26	26	25
16	28	28	27	27
17	30	29	29	29
18	32	31	31	31
19	33	33	33	32
20	35	35	34	34
21	37	36	36	36
22	38	38	38	37
23	40	40	39	39
24	42	42	41	41
25	44	43	43	43
26	46	45	45	44
27	47	47	46	46
28	49	49	48	48
29	51	50	50	49
30	52	52	52	51
31	54	54	53	53
32	56	55	55	54
33	58	57	57	56
34	60	59	58	58
35	61	61	60	59
36	63	62	62	61
37	65	64	64	63
38	66	66	65	65
39	68	68	67	66
40	70	69	69	68
41	72	71	70	70
42	74	73	72	71
43	75	75	74	73
44	77	76	76	75
45	79	78	77	77
46	80	80	79	78
47	82	81	81	80
48	84	83	82	82
49	86	85	84	83
50	88	87	86	85
51	89	88	88	87
52	91	90	89	88
53	93	92	91	90
54	94	94	93	92
55	96	95	94	93
56	98	97	96	95
57	100	99	98	97
58	102	101	100	99
59	103	102	101	100
60	105	104	103	102
″	105 Proportional Parts	104	103	102

TABLE II

″	101	100	99	98	97	96	95	94	93	92	91	90	2	1
							Proportional Parts							
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	2	2	2	2	2	2	2	2	2	2	2	1	0	0
2	3	3	3	3	3	3	3	3	3	3	3	3	0	0
3	5	5	5	5	5	5	5	5	5	5	5	5	0	0
4	7	7	7	7	6	6	6	6	6	6	6	6	0	0
5	8	8	8	8	8	8	8	8	8	8	8	7	0	0
6	10	10	10	10	10	10	10	9	9	9	9	9	0	0
7	12	12	12	11	11	11	11	11	11	11	11	11	0	0
8	13	13	13	13	13	13	13	13	12	12	12	12	0	0
9	15	15	15	15	15	14	14	14	14	14	14	13	0	0
10	17	17	16	16	16	16	16	16	16	15	15	15	0	0
11	19	18	18	18	18	18	17	17	17	17	17	17	0	0
12	20	20	20	20	19	19	19	19	19	18	18	18	0	0
13	22	22	21	21	21	21	21	20	20	20	20	19	0	0
14	24	23	23	23	23	22	22	22	22	21	21	21	0	0
15	25	25	25	24	24	24	24	23	23	23	23	23	0	0
16	27	27	26	26	26	26	25	25	25	25	24	24	1	0
17	29	28	28	28	27	27	27	27	26	26	26	25	1	0
18	30	30	30	29	29	29	28	28	28	28	27	27	1	0
19	32	32	31	31	31	30	30	30	29	29	29	29	1	0
20	34	33	33	33	32	32	32	31	31	31	30	30	1	0
21	35	35	35	34	34	34	33	33	33	32	32	31	1	0
22	37	37	36	36	36	35	35	34	34	34	33	33	1	0
23	39	38	38	38	37	37	36	36	36	35	35	35	1	0
24	40	40	40	39	39	38	38	38	37	37	36	36	1	0
25	42	42	41	41	40	40	40	39	39	38	38	37	1	0
26	44	43	43	42	42	42	41	41	40	40	39	39	1	0
27	45	45	45	44	44	43	43	42	42	41	41	41	1	0
28	47	47	46	46	45	45	44	44	43	43	42	42	1	0
29	49	48	48	47	47	46	46	45	45	44	44	43	1	0
30	50	50	50	49	48	48	48	47	46	46	46	45	1	0
31	52	52	51	51	50	50	49	49	48	48	47	47	1	1
32	54	53	53	52	52	51	51	50	50	49	49	48	1	1
33	56	55	54	54	53	53	52	52	51	51	50	49	1	1
34	57	57	56	56	55	54	54	53	53	52	52	51	1	1
35	59	58	58	57	57	56	55	55	54	54	53	53	1	1
36	61	60	59	59	58	58	57	56	56	55	55	54	1	1
37	62	62	61	60	60	59	59	58	57	57	56	55	1	1
38	64	63	63	62	61	61	60	60	59	58	58	57	1	1
39	66	65	64	64	63	62	62	61	60	60	59	59	1	1
40	67	67	66	65	65	64	63	63	62	61	61	60	1	1
41	69	68	68	67	66	66	65	64	64	63	62	61	1	1
42	71	70	69	69	68	67	66	66	65	64	64	63	1	1
43	72	72	71	70	70	69	68	67	67	66	65	65	1	1
44	74	73	73	72	71	70	70	69	68	67	67	66	1	1
45	76	75	74	73	73	72	71	71	70	69	68	67	2	1
46	77	77	76	75	74	74	73	72	71	71	70	69	2	1
47	79	78	78	77	76	75	74	74	73	72	71	71	2	1
48	81	80	79	78	78	77	76	75	74	74	73	72	2	1
49	82	82	81	80	79	78	78	77	76	75	74	73	2	1
50	84	83	82	82	81	80	79	78	78	77	76	75	2	1
51	86	85	84	83	82	82	81	80	79	78	77	77	2	1
52	88	87	86	85	84	83	82	81	81	80	79	78	2	1
53	89	88	87	87	86	85	84	83	82	81	80	79	2	1
54	91	90	89	88	87	86	86	85	84	83	82	81	2	1
55	93	92	91	90	89	88	87	86	85	84	83	83	2	1
56	94	93	92	91	91	90	89	88	87	86	85	84	2	1
57	96	95	94	93	92	91	90	89	88	87	86	85	2	1
58	98	97	96	95	94	93	92	91	90	89	88	87	2	1
59	99	98	97	96	95	94	93	92	91	90	89	89	2	1
60	101	100	99	98	97	96	95	94	93	92	91	90	2	1
″	101	100	99	98	97	96	95	94	93	92	91	90	2	1
							Proportional Parts							

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	14356	89	85644	14780	92	85220	00425	1	99575	60
1	445	90	555	872	91	128	426	2	574	59
2	535	89	465	963	91	037	428	2	572	58
3	624	90	376	15054	91	84946	430	2	570	57
4	714	89	286	145	91	855	432	2	568	56
5	803	88	197	236	91	764	434	1	566	55
6	891	89	109	327	90	673	435	2	565	54
7	980	89	020	417	91	583	437	2	563	53
8	15069	88	84931	508	90	492	439	2	561	52
9	157	88	843	598	90	402	441	2	559	51
10	245	88	755	688	89	312	443	1	557	50
11	333	88	667	777	90	223	444	2	556	49
12	421	87	579	867	89	133	446	2	554	48
13	508	88	492	956	90	044	448	2	552	47
14	596	87	404	16046	89	83954	450	2	550	46
15	683	87	317	135	89	865	452	2	548	45
16	770	87	230	224	88	776	454	1	546	44
17	857	87	143	312	89	688	455	2	545	43
18	944	86	056	401	88	599	457	2	543	42
19	16030	86	83970	489	88	511	459	2	541	41
20	116	87	884	577	88	423	461	2	539	40
21	203	86	797	665	88	335	463	2	537	39
22	289	85	711	753	88	247	465	2	535	38
23	374	86	626	841	87	159	467	1	533	37
24	460	85	540	928	88	072	468	2	532	36
25	545	86	455	17016	87	82984	470	2	530	35
26	631	85	369	103	87	897	472	2	528	34
27	716	85	284	190	87	810	474	2	526	33
28	801	85	199	277	86	723	476	2	524	32
29	886	84	114	363	87	637	478	2	522	31
30	16970	85	83030	17450	86	82550	00480	2	99520	30
31	17055	84	82945	536	86	464	482	1	518	29
32	139	84	861	622	86	378	483	2	517	28
33	223	84	777	708	86	292	485	2	515	27
34	307	84	693	794	86	206	487	2	513	26
35	391	83	609	880	85	120	489	2	511	25
36	474	84	526	965	86	035	491	2	509	24
37	558	83	442	18051	85	81949	493	2	507	23
38	641	83	359	136	85	864	495	2	505	22
39	724	83	276	221	85	779	497	2	503	21
40	807	83	193	306	85	694	499	2	501	20
41	890	83	110	391	84	609	501	2	499	19
42	973	82	027	475	85	525	503	2	497	18
43	18055	82	81945	560	84	440	505	1	495	17
44	137	83	863	644	84	356	506	2	494	16
45	220	82	780	728	84	272	508	2	492	15
46	302	81	698	812	84	188	510	2	490	14
47	383	82	617	896	83	104	512	2	488	13
48	465	82	535	979	84	021	514	2	486	12
49	547	81	453	19063	83	80937	516	2	484	11
50	628	81	372	146	83	854	518	2	482	10
51	709	81	291	229	83	771	520	2	480	9
52	790	81	210	312	83	688	522	2	478	8
53	871	81	129	395	83	605	524	2	476	7
54	952	81	048	478	83	522	526	2	474	6
55	19033	80	80967	561	82	439	528	2	472	5
56	113	80	887	643	82	357	530	2	470	4
57	193	80	807	725	82	275	532	2	468	3
58	273	80	727	807	82	193	534	2	466	2
59	353	80	647	889	82	111	536	2	464	1
60	19433		80567	19971		80029	00538		99462	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts 92	91	90
0	0	0	0
1	2	2	1
2	3	3	3
3	5	5	5
4	6	6	6
5	8	8	7
6	9	9	9
7	11	11	11
8	12	12	12
9	14	14	13
10	15	15	15
11	17	17	17
12	18	18	18
13	20	20	19
14	21	21	21
15	23	23	23
16	25	24	24
17	26	26	25
18	28	27	27
19	29	29	29
20	31	30	30
21	32	32	31
22	34	33	33
23	35	35	35
24	37	36	36
25	38	38	37
26	40	39	39
27	41	41	41
28	43	42	42
29	44	44	43
30	46	46	45
31	48	47	47
32	49	49	48
33	51	50	49
34	52	52	51
35	54	53	53
36	55	55	54
37	57	56	55
38	58	58	57
39	60	59	59
40	61	61	60
41	63	62	61
42	64	64	63
43	66	65	65
44	67	67	66
45	69	68	67
46	71	70	69
47	72	71	71
48	74	73	72
49	75	74	73
50	77	76	75
51	78	77	77
52	80	79	78
53	81	80	79
54	83	82	81
55	84	83	83
56	86	85	84
57	87	86	85
58	89	88	87
59	90	89	89
60	92	91	90
″	92 Proportional Parts	91	90

TABLE II

″	89	88	87	86	85	84	83	82	81	80	2	1
	Proportional Parts											
0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	0	0
2	3	3	3	3	3	3	3	3	3	3	0	0
3	4	4	4	4	4	4	4	4	4	4	0	0
4	6	6	6	6	6	6	6	5	5	5	0	0
5	7	7	7	7	7	7	7	7	7	7	0	0
6	9	9	9	9	8	8	8	8	8	8	0	0
7	10	10	10	10	10	10	10	10	9	9	0	0
8	12	12	12	11	11	11	11	11	11	11	0	0
9	13	13	13	13	13	13	12	12	12	12	0	0
10	15	15	14	14	14	14	14	14	14	13	0	0
11	16	16	16	16	16	15	15	15	15	15	0	0
12	18	18	17	17	17	17	17	16	16	16	0	0
13	19	19	19	19	18	18	18	18	18	17	0	0
14	21	21	20	20	20	20	19	19	19	19	0	0
15	22	22	22	21	21	21	21	21	20	20	0	0
16	24	23	23	23	23	22	22	22	22	21	1	0
17	25	25	25	24	24	24	24	23	23	23	1	0
18	27	26	26	26	26	25	25	25	24	24	1	0
19	28	28	28	27	27	27	26	26	26	25	1	0
20	30	29	29	29	28	28	28	27	27	27	1	0
21	31	31	30	30	30	29	29	29	28	28	1	0
22	33	32	32	32	31	31	30	30	30	29	1	0
23	34	34	33	33	33	32	32	31	31	31	1	0
24	36	35	35	34	34	34	33	33	32	32	1	0
25	37	37	36	36	35	35	35	34	34	33	1	0
26	39	38	38	37	37	36	36	36	35	35	1	0
27	40	40	39	39	38	38	37	37	36	36	1	0
28	42	41	41	40	40	39	39	38	38	37	1	0
29	43	43	42	42	41	41	40	40	39	39	1	0
30	44	44	44	43	42	42	42	41	40	40	1	0
31	46	45	45	44	44	43	43	42	42	41	1	1
32	47	47	46	46	45	45	44	44	43	43	1	1
33	49	48	48	47	47	46	46	45	45	44	1	1
34	50	50	49	49	48	48	47	46	46	45	1	1
35	52	51	51	50	50	49	48	48	47	47	1	1
36	53	53	52	52	51	50	50	49	49	48	1	1
37	55	54	54	53	52	52	51	51	50	49	1	1
38	56	56	55	54	54	53	53	52	51	51	1	1
39	58	57	57	56	55	55	54	53	53	52	1	1
40	59	59	58	57	57	56	55	55	54	53	1	1
41	61	60	59	59	58	57	57	56	55	55	1	1
42	62	62	61	60	60	59	58	57	57	56	1	1
43	64	63	62	62	61	60	59	59	58	57	1	1
44	65	65	64	63	62	62	61	60	59	59	1	1
45	67	66	65	65	64	63	62	61	61	60	2	1
46	68	67	67	66	65	64	64	63	62	61	2	1
47	70	69	68	67	67	66	65	64	63	63	2	1
48	71	70	70	69	68	67	66	66	65	64	2	1
49	73	72	71	70	69	69	68	67	66	65	2	1
50	74	73	72	72	71	70	69	68	68	67	2	1
51	76	75	74	73	72	71	71	70	69	68	2	1
52	77	76	75	75	74	73	72	71	70	69	2	1
53	79	78	77	76	75	74	73	72	72	71	2	1
54	80	79	78	77	76	76	75	74	73	72	2	1
55	82	81	80	79	78	77	76	75	74	73	2	1
56	83	82	81	80	79	78	77	77	76	75	2	1
57	85	84	83	82	81	80	79	78	77	76	2	1
58	86	85	84	83	82	81	80	79	78	77	2	1
59	88	87	86	85	84	83	82	81	80	79	2	1
60	89	88	87	86	85	84	83	82	81	80	2	1
″	89	88	87	86	85	84	83	82	81	80	2	1
	Proportional Parts											

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	19433	80	80567	19971	82	80029	00538	2	99462	60
1	513	79	487	20053	81	79947	540	2	460	59
2	592	80	408	134	82	866	542	2	458	58
3	672	79	328	216	81	784	544	2	456	57
4	751	79	249	297	81	703	546	2	454	56
5	830	79	170	378	81	622	548	2	452	55
6	909	79	091	459	81	541	550	2	450	54
7	988	79	012	540	81	460	552	2	448	53
8	20067	78	79933	621	80	379	554	2	446	52
9	145	78	855	701	81	299	556	2	444	51
10	223	79	777	782	80	218	558	2	442	50
11	302	78	698	862	80	138	560	2	440	49
12	380	78	620	942	80	058	562	2	438	48
13	458	77	542	21022	80	78978	564	2	436	47
14	535	78	465	102	80	898	566	2	434	46
15	613	78	387	182	79	818	568	3	432	45
16	691	77	309	261	80	739	571	2	429	44
17	768	77	232	341	79	659	573	2	427	43
18	845	77	155	420	79	580	575	2	425	42
19	922	77	078	499	79	501	577	2	423	41
20	999	77	001	578	79	422	579	2	421	40
21	21076	77	78924	657	79	343	581	2	419	39
22	153	76	847	736	78	264	583	2	417	38
23	229	77	771	814	79	186	585	2	415	37
24	306	76	694	893	78	107	587	2	413	36
25	382	76	618	971	78	029	589	2	411	35
26	458	76	542	22049	78	77951	591	2	409	34
27	534	76	466	127	78	873	593	3	407	33
28	610	75	390	205	78	795	596	2	404	32
29	685	76	315	283	78	717	598	2	402	31
30	21761	75	78239	22361	77	77639	00600	2	99400	30
31	836	76	164	438	78	562	602	2	398	29
32	912	75	088	516	77	484	604	2	396	28
33	987	75	013	593	77	407	606	2	394	27
34	22062	75	77938	670	77	330	608	2	392	26
35	137	74	863	747	77	253	610	2	390	25
36	211	75	789	824	77	176	612	3	388	24
37	286	75	714	901	76	099	615	2	385	23
38	361	74	639	977	77	023	617	2	383	22
39	435	74	565	23054	76	76946	619	2	381	21
40	509	74	491	130	76	870	621	2	379	20
41	583	74	417	206	77	794	623	2	377	19
42	657	74	343	283	76	717	625	3	375	18
43	731	74	269	359	76	641	628	2	372	17
44	805	73	195	435	75	565	630	2	370	16
45	878	74	122	510	76	490	632	2	368	15
46	952	73	048	586	75	414	634	2	366	14
47	23025	73	76975	661	76	339	636	2	364	13
48	098	73	902	737	75	263	638	3	362	12
49	171	73	829	812	75	188	641	2	359	11
50	244	73	756	887	75	113	643	2	357	10
51	317	73	683	962	75	038	645	2	355	9
52	390	72	610	24037	75	75963	647	2	353	8
53	462	73	538	112	74	888	649	3	351	7
54	535	72	465	186	75	814	652	2	348	6
55	607	72	393	261	74	739	654	2	346	5
56	679	73	321	335	75	665	656	2	344	4
57	752	71	248	410	74	590	658	2	342	3
58	823	72	177	484	74	516	660	3	340	2
59	895	72	105	558	74	442	663	2	337	1
60	23967		76033	24632		75368	00665		99335	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

99° 80°

″	82	81	80	79	78	77	76	75	74	73	72	71	3	2
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
2	3	3	3	3	3	3	3	2	2	2	2	2	0	0
3	4	4	4	4	4	4	4	4	4	4	4	4	0	0
4	5	5	5	5	5	5	5	5	5	5	5	5	0	0
5	7	7	7	7	7	6	6	6	6	6	6	6	0	0
6	8	8	8	8	8	8	8	8	7	7	7	7	0	0
7	10	9	9	9	9	9	9	9	9	9	8	8	0	0
8	11	11	11	11	10	10	10	10	10	10	10	9	0	0
9	12	12	12	12	12	12	11	11	11	11	11	11	0	0
10	14	14	13	13	13	13	13	12	12	12	12	12	0	0
11	15	15	15	14	14	14	14	14	14	13	13	13	1	0
12	16	16	16	16	16	15	15	15	15	15	14	14	1	0
13	18	18	17	17	17	17	16	16	16	16	16	15	1	0
14	19	19	19	18	18	18	18	18	17	17	17	17	1	0
15	21	20	20	20	19	19	19	19	19	18	18	18	1	0
16	22	22	21	21	21	21	20	20	20	19	19	19	1	1
17	23	23	23	22	22	22	22	21	21	21	20	20	1	1
18	25	24	24	24	23	23	23	22	22	22	22	21	1	1
19	26	26	25	25	25	24	24	24	23	23	23	22	1	1
20	27	27	27	26	26	26	25	25	25	24	24	24	1	1
21	29	28	28	28	27	27	27	26	26	26	25	25	1	1
22	30	30	29	29	29	28	28	28	27	27	26	26	1	1
23	31	31	31	30	30	30	29	29	28	28	28	27	1	1
24	33	32	32	32	31	31	30	30	30	29	29	28	1	1
25	34	34	33	33	33	32	32	31	31	30	30	30	1	1
26	36	35	35	34	34	33	33	32	32	32	31	31	1	1
27	37	36	36	36	35	35	34	34	33	33	32	32	1	1
28	38	38	37	37	36	36	35	35	35	34	34	33	1	1
29	40	39	39	38	38	37	37	36	36	35	35	34	1	1
30	41	40	40	40	39	38	38	38	37	36	36	36	2	1
31	42	42	41	41	40	40	39	39	38	38	37	37	2	1
32	44	43	43	42	42	41	41	40	39	39	38	38	2	1
33	45	45	44	43	43	42	42	41	41	40	40	39	2	1
34	46	46	45	45	44	44	43	42	42	41	41	40	2	1
35	48	47	47	46	45	45	44	44	43	43	42	41	2	1
36	49	49	48	47	47	46	46	45	44	44	43	43	2	1
37	51	50	49	49	48	47	47	46	46	45	44	44	2	1
38	52	51	51	50	49	49	48	48	47	46	46	45	2	1
39	53	53	52	51	51	50	49	49	48	47	47	46	2	1
40	55	54	53	53	52	51	51	50	49	49	48	47	2	1
41	56	55	55	54	53	53	52	51	51	50	49	49	2	1
42	57	57	56	55	55	54	53	52	52	51	50	50	2	1
43	59	58	57	57	56	55	54	54	53	52	52	51	2	1
44	60	59	59	58	57	56	56	55	54	54	53	52	2	1
45	61	61	60	59	59	58	57	56	55	55	54	53	2	2
46	63	62	61	61	60	59	58	58	57	56	55	54	2	2
47	64	63	63	62	61	60	60	59	58	57	56	56	2	2
48	66	65	64	63	62	62	61	60	59	58	58	57	2	2
49	67	66	65	65	64	63	62	61	60	60	59	58	2	2
50	68	68	67	66	65	64	63	62	62	61	60	59	2	2
51	70	69	68	67	66	65	65	64	63	62	61	60	3	2
52	71	70	69	68	68	67	66	65	64	63	62	62	3	2
53	72	72	71	70	69	68	67	66	65	64	64	63	3	2
54	74	73	72	71	70	69	68	68	67	66	65	64	3	2
55	75	74	73	72	71	71	70	69	68	67	66	65	3	2
56	77	76	75	74	73	72	71	70	69	68	67	66	3	2
57	78	77	76	75	74	73	72	71	70	69	68	67	3	2
58	79	78	77	76	75	74	73	72	72	71	70	69	3	2
59	81	80	79	78	77	76	75	74	73	72	71	70	3	2
60	82	81	80	79	78	77	76	75	74	73	72	71	3	2
″	82	81	80	79	78	77	76	75	74	73	72	71	3	2

Proportional Parts

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	23967		76033	24632		75368	00665		99335	60
1	24039	72	75961	706	74	294	667	2	333	59
2	110	71	890	779	73	221	669	2	331	58
3	181	71	819	853	74	147	672	3	328	57
4	253	72	747	926	73	074	674	2	326	56
5	324	71	676	25000	74	000	676	2	324	55
6	395	71	605	073	73	74927	678	2	322	54
7	466	71	534	146	73	854	681	3	319	53
8	536	70	464	219	73	781	683	2	317	52
9	607	71	393	292	73	708	685	2	315	51
10	677	70	323	365	73	635	687	2	313	50
11	748	71	252	437	72	563	690	3	310	49
12	818	70	182	510	73	490	692	2	308	48
13	888	70	112	582	72	418	694	2	306	47
14	958	70	042	655	73	345	696	2	304	46
15	25028	70	74972	727	72	273	699	3	301	45
16	098	70	902	799	72	201	701	2	299	44
17	168	70	832	871	72	129	703	2	297	43
18	237	69	763	943	72	057	706	3	294	42
19	307	70	693	26015	72	73985	708	2	292	41
20	376	69	624	086	71	914	710	2	290	40
21	445	69	555	158	72	842	712	2	288	39
22	514	69	486	229	71	771	715	3	285	38
23	583	69	417	301	72	699	717	2	283	37
24	652	69	348	372	71	628	719	2	281	36
25	721	69	279	443	71	557	722	3	278	35
26	790	69	210	514	71	486	724	2	276	34
27	858	68	142	585	71	415	726	2	274	33
28	927	69	073	655	70	345	729	3	271	32
29	995	68	005	726	71	274	731	2	269	31
30	26063	68	73937	26797	71	73203	00733	2	99267	30
31	131	68	869	867	70	133	736	3	264	29
32	199	68	801	937	70	063	738	2	262	28
33	267	68	733	27008	71	72992	740	2	260	27
34	335	68	665	078	70	922	743	3	257	26
35	·403	68	597	148	70	852	745	2	255	25
36	470	67	530	218	70	782	748	3	252	24
37	538	68	462	288	70	712	750	2	250	23
38	605	67	395	357	69	643	752	2	248	22
39	672	67	328	427	70	573	755	3	245	21
40	739	67	261	496	69	504	757	2	243	20
41	806	67	194	566	70	434	759	2	241	19
42	873	67	127	635	69	365	762	3	238	18
43	940	67	060	704	69	296	764	2	236	17
44	27007	67	72993	773	69	227	767	3	233	16
45	073	66	927	842	69	158	769	2	231	15
46	140	67	860	911	69	089	771	2	229	14
47	206	66	794	980	69	020	774	3	226	13
48	273	67	727	28049	69	71951	776	2	224	12
49	339	66	661	117	68	883	779	3	221	11
50	405	66	595	186	69	814	781	2	219	10
51	471	66	529	254	68	746	783	2	217	9
52	537	66	463	323	69	677	786	3	214	8
53	602	65	398	391	68	609	788	2	212	7
54	668	66	332	459	68	541	791	3	209	6
55	734	66	266	527	68	473	793	2	207	5
56	799	65	201	595	68	405	796	3	204	4
57	864	65	136	662	67	338	798	2	202	3
58	930	66	070	730	68	270	800	2	200	2
59	995	65	005	798	68	202	803	3	197	1
60	28060	65	71940	28865	67	71135	00805	2	99195	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts 74	73	72	71	70	69	68	67	66	65	3	2
0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	0	0
2	2	2	2	2	2	2	2	2	2	2	0	0
3	4	4	4	4	3	3	3	3	3	3	0	0
4	5	5	5	5	5	5	5	4	4	4	0	0
5	6	6	6	6	6	6	6	6	5	5	0	0
6	7	7	7	7	7	7	7	7	7	6	0	0
7	9	9	8	8	8	8	8	8	8	8	0	0
8	10	10	10	9	9	9	9	9	9	9	0	0
9	11	11	11	11	11	10	10	10	10	10	0	0
10	12	12	12	12	12	12	11	11	11	11	0	0
11	14	13	13	13	13	13	12	12	12	12	1	0
12	15	15	14	14	14	14	14	13	13	13	1	0
13	16	16	16	15	15	15	15	15	14	14	1	0
14	17	17	17	17	16	16	16	16	15	15	1	0
15	19	18	18	18	17	17	17	17	17	16	1	0
16	20	19	19	19	19	18	18	18	18	17	1	1
17	21	21	20	20	20	20	19	19	19	18	1	1
18	22	22	22	21	21	21	20	20	20	20	1	1
19	23	23	23	22	22	22	22	21	21	21	1	1
20	25	24	24	24	23	23	23	22	22	22	1	1
21	26	26	25	25	25	24	24	23	23	23	1	1
22	27	27	26	26	26	25	25	25	24	24	1	1
23	28	28	28	27	27	26	26	26	25	25	1	1
24	30	29	29	28	28	28	27	27	26	26	1	1
25	31	30	30	30	29	29	28	28	27	27	1	1
26	32	32	31	31	30	30	29	29	29	28	1	1
27	33	33	32	32	31	31	31	30	30	29	1	1
28	35	34	34	33	33	32	32	31	31	30	1	1
29	36	35	35	34	34	33	33	32	32	31	1	1
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31	38	38	37	37	36	36	35	35	34	34	2	1
32	39	39	38	38	37	37	36	36	35	35	2	1
33	41	40	40	39	39	38	37	37	36	36	2	1
34	42	41	41	40	40	39	39	38	37	37	2	1
35	43	43	42	41	41	40	40	39	39	38	2	1
36	44	44	43	43	42	41	41	40	40	39	2	1
37	46	45	44	44	43	43	42	41	41	40	2	1
38	47	46	46	45	44	44	43	42	42	41	2	1
39	48	47	47	46	45	45	44	44	43	42	2	1
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41	51	50	49	49	48	47	46	46	45	44	2	1
42	52	51	50	50	49	48	48	47	46	46	2	1
43	53	52	52	51	50	49	49	48	47	47	2	1
44	54	54	53	52	51	51	50	49	48	48	2	1
45	55	55	54	53	53	52	51	50	49	49	2	2
46	57	56	55	54	54	53	52	51	51	50	2	2
47	58	57	56	56	55	54	53	52	52	51	2	2
48	59	58	58	57	56	55	54	54	53	52	2	2
49	60	60	59	58	57	56	56	55	54	53	2	2
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52	64	63	62	62	61	60	59	58	57	56	3	2
53	65	64	64	63	62	61	60	59	58	57	3	2
54	67	66	65	64	63	62	61	60	59	58	3	2
55	68	67	66	65	64	63	62	61	61	60	3	2
56	69	68	67	66	65	64	63	63	62	61	3	2
57	70	69	68	67	67	66	65	64	63	62	3	2
58	72	71	70	69	68	67	66	65	64	63	3	2
59	73	72	71	70	69	68	67	66	65	64	3	2
60	74	73	72	71	70	69	68	67	66	65	3	2
″	74 Proportional Parts	73	72	71	70	69	68	67	66	65	3	2

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	28060		71940	28865		71135	00805		99195	60
1	125	65	875	933	68	067	808	3	192	59
2	190	65	810	29000	67	000	810	2	190	58
3	254	64	746	067	67	70933	813	3	187	57
4	319	65	681	134	67	866	815	2	185	56
5	384	65	616	201	67	799	818	3	182	55
6	448	64	552	268	67	732	820	2	180	54
7	512	64	488	335	67	665	823	3	177	53
8	577	65	423	402	67	598	825	2	175	52
9	641	64	359	468	66	532	828	3	172	51
10	705	64	295	535	67	465	830	2	170	50
11	769	64	231	601	66	399	833	3	167	49
12	833	64	167	668	67	332	835	2	165	48
13	896	63	104	734	66	266	838	3	162	47
14	960	64	040	800	66	200	840	2	160	46
15	29024	64	70976	866	66	134	843	3	157	45
16	087	63	913	932	66	068	845	2	155	44
17	150	63	850	998	66	002	848	3	152	43
18	214	64	786	30064	66	69936	850	2	150	42
19	277	63	723	130	66	870	853	3	147	41
20	340	63	660	195	65	805	855	2	145	40
21	403	63	597	261	66	739	858	3	142	39
22	466	63	534	326	65	674	860	2	140	38
23	529	63	471	391	65	609	863	3	137	37
24	591	62	409	457	66	543	865	2	135	36
25	654	63	346	522	65	478	868	3	132	35
26	716	62	284	587	65	413	870	2	130	34
27	779	63	221	652	65	348	873	3	127	33
28	841	62	159	717	65	283	876	3	124	32
29	903	62	097	782	65	218	878	2	122	31
30	29966	63	70034	30846	64	69154	00881	3	99119	30
31	30028	62	69972	911	65	089	883	2	117	29
32	090	62	910	975	64	025	886	3	114	28
33	151	61	849	31040	65	68960	888	2	112	27
34	213	62	787	104	64	896	891	3	109	26
35	275	62	725	168	64	832	894	3	106	25
36	336	61	664	233	65	767	896	2	104	24
37	398	62	602	297	64	703	899	3	101	23
38	459	61	541	361	64	639	901	2	099	22
39	521	62	479	425	64	575	904	3	096	21
40	582	61	418	489	64	511	907	3	093	20
41	643	61	357	552	63	448	909	2	091	19
42	704	61	296	616	64	384	912	3	088	18
43	765	61	235	679	63	321	914	2	086	17
44	826	61	174	743	64	257	917	3	083	16
45	887	61	113	806	63	194	920	3	080	15
46	947	60	053	870	64	130	922	2	078	14
47	31008	61	68992	933	63	067	925	3	075	13
48	068	60	932	996	63	004	928	3	072	12
49	129	61	871	32059	63	67941	930	2	070	11
50	189	60	811	122	63	878	933	3	067	10
51	250	61	750	185	63	815	936	3	064	9
52	310	60	690	248	63	752	938	2	062	8
53	370	60	630	311	63	689	941	3	059	7
54	430	60	570	373	62	627	944	3	056	6
55	490	60	510	436	63	564	946	2	054	5
56	549	59	451	498	62	502	949	3	051	4
57	609	60	391	561	63	439	952	3	048	3
58	669	60	331	623	62	377	954	2	046	2
59	728	59	272	685	62	315	957	3	043	1
60	31788	60	68212	32747	62	67253	00960	3	99040	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

Proportional Parts

″	68	67	66	65	64	63	62	61	60	59	3	2
0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	0	0
2	2	2	2	2	2	2	2	2	2	2	0	0
3	3	3	3	3	3	3	3	3	3	3	0	0
4	5	4	4	4	4	4	4	4	4	4	0	0
5	6	6	5	5	5	5	5	5	5	5	0	0
6	7	7	7	6	6	6	6	6	6	6	0	0
7	8	8	8	8	7	7	7	7	7	7	0	0
8	9	9	9	9	9	8	8	8	8	8	0	0
9	10	10	10	10	10	9	9	9	9	9	0	0
10	11	11	11	11	11	10	10	10	10	10	0	0
11	12	12	12	12	12	12	11	11	11	11	1	0
12	14	13	13	13	13	13	12	12	12	12	1	0
13	15	15	14	14	14	14	13	13	13	13	1	0
14	16	16	15	15	15	15	14	14	14	14	1	0
15	17	17	17	16	16	16	15	15	15	15	1	0
16	18	18	18	17	17	17	17	16	16	16	1	1
17	19	19	19	18	18	18	18	17	17	17	1	1
18	20	20	20	20	19	19	19	18	18	18	1	1
19	22	21	21	21	20	20	20	19	19	19	1	1
20	23	22	22	22	21	21	21	20	20	20	1	1
21	24	23	23	23	22	22	22	21	21	21	1	1
22	25	25	24	24	23	23	23	22	22	22	1	1
23	26	26	25	25	25	24	24	23	23	23	1	1
24	27	27	26	26	26	25	25	24	24	24	1	1
25	28	28	27	27	27	26	26	25	25	25	1	1
26	29	29	29	28	28	27	27	26	26	26	1	1
27	31	30	30	29	29	28	28	27	27	27	1	1
28	32	31	31	30	30	29	29	28	28	28	1	1
29	33	32	32	31	31	30	30	29	29	29	1	1
30	34	34	33	32	32	32	31	30	30	30	2	1
31	35	35	34	34	33	33	32	32	31	30	2	1
32	36	36	35	35	34	34	33	33	32	31	2	1
33	37	37	36	36	35	35	34	34	33	32	2	1
34	39	38	37	37	36	36	35	35	34	33	2	1
35	40	39	39	38	37	37	36	36	35	34	2	1
36	41	40	40	39	38	38	37	37	36	35	2	1
37	42	41	41	40	39	39	38	38	37	36	2	1
38	43	42	42	41	41	40	39	39	38	37	2	1
39	44	44	43	42	42	41	40	40	39	38	2	1
40	45	45	44	43	43	42	41	41	40	39	2	1
41	46	46	45	44	44	43	42	42	41	40	2	1
42	48	47	46	46	45	44	43	43	42	41	2	1
43	49	48	47	47	46	45	44	44	43	42	2	1
44	50	49	48	48	47	46	45	45	44	43	2	1
45	51	50	49	49	48	47	47	46	45	44	2	2
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47	53	52	52	51	50	49	49	48	47	46	2	2
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58	66	65	64	63	62	61	60	59	58	57	3	2
59	67	66	65	64	63	62	61	60	59	58	3	2
60	68	67	66	65	64	63	62	61	60	59	3	2
″	68	67	66	65	64	63	62	61	60	59	3	2

Proportional Parts

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	31788	59	68212	32747	63	67253	00960	2	99040	60
1	847	60	153	810	62	190	962	3	038	59
2	907	59	093	872	61	128	965	3	035	58
3	966	59	034	933	62	067	968	2	032	57
4	32025	59	67975	995	62	005	970	3	030	56
5	084	59	916	33057	62	66943	973	3	027	55
6	143	59	857	119	61	881	976	2	024	54
7	202	59	798	180	62	820	978	3	022	53
8	261	58	739	242	61	758	981	3	019	52
9	319	59	681	303	62	697	984	3	016	51
10	378	59	622	365	61	635	987	2	013	50
11	437	58	563	426	61	574	989	3	011	49
12	495	58	505	487	61	513	992	3	008	48
13	553	59	447	548	61	452	995	3	005	47
14	612	58	388	609	61	391	998	2	002	46
15	670	58	330	670	61	330	01000	3	000	45
16	728	58	272	731	61	269	003	3	98997	44
17	786	58	214	792	61	208	006	3	994	43
18	844	58	156	853	60	147	009	2	991	42
19	902	58	098	913	61	087	011	3	989	41
20	960	58	040	974	60	026	014	3	986	40
21	33018	57	66982	34034	61	65966	017	3	983	39
22	075	58	925	095	60	905	020	2	980	38
23	133	57	867	155	60	845	022	3	978	37
24	190	58	810	215	61	785	025	3	975	36
25	248	57	752	276	60	724	028	3	972	35
26	305	57	695	336	60	664	031	2	969	34
27	362	58	638	396	60	604	033	3	967	33
28	420	57	580	456	60	544	036	3	964	32
29	477	57	523	516	60	484	039	3	961	31
30	33534	57	66466	34576	59	65424	01042	3	98958	30
31	591	56	409	635	60	365	045	2	955	29
32	647	57	353	695	60	305	047	3	953	28
33	704	57	296	755	59	245	050	3	950	27
34	761	57	239	814	60	186	053	3	947	26
35	818	56	182	874	59	126	056	3	944	25
36	874	57	126	933	59	067	059	3	941	24
37	931	56	069	992	59	008	062	2	938	23
38	987	56	013	35051	60	64949	064	3	936	22
39	34043	57	65957	111	59	889	067	3	933	21
40	100	56	900	170	59	830	070	3	930	20
41	156	56	844	229	59	771	073	3	927	19
42	212	56	788	288	59	712	076	3	924	18
43	268	56	732	347	58	653	079	2	921	17
44	324	56	676	405	59	595	081	3	919	16
45	380	56	620	464	59	536	084	3	916	15
46	436	55	564	523	58	477	087	3	913	14
47	491	56	509	581	59	419	090	3	910	13
48	547	55	453	640	58	360	093	3	907	12
49	602	56	398	698	59	302	096	3	904	11
50	658	55	342	757	58	243	099	3	901	10
51	713	56	287	815	58	185	102	2	898	9
52	769	55	231	873	58	127	104	3	896	8
53	824	55	176	931	58	069	107	3	893	7
54	879	55	121	989	58	011	110	3	890	6
55	934	55	066	36047	58	63953	113	3	887	5
56	989	55	011	105	58	895	116	3	884	4
57	35044	55	64956	163	58	837	119	3	881	3
58	099	55	901	221	58	779	122	3	878	2
59	154	55	846	279	57	721	125	3	875	1
60	35209		64791	36336		63664	01128		98872	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

Proportional Parts

″	63	62	61	60	59	58	57	56	55	3	2
0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	0	0
2	2	2	2	2	2	2	2	2	2	0	0
3	3	3	3	3	3	3	3	3	3	0	0
4	4	4	4	4	4	4	4	4	4	0	0
5	5	5	5	5	5	5	5	5	5	0	0
6	6	6	6	6	6	6	6	6	6	0	0
7	7	7	7	7	7	7	7	7	6	0	0
8	8	8	8	8	8	8	8	7	7	0	0
9	9	9	9	9	9	9	9	8	8	0	0
10	10	10	10	10	10	10	10	9	9	0	0
11	12	11	11	11	11	11	10	10	10	1	0
12	13	12	12	12	12	12	11	11	11	1	0
13	14	13	13	13	13	13	12	12	12	1	0
14	15	14	14	14	14	14	13	13	13	1	0
15	16	15	15	15	15	14	14	14	14	1	0
16	17	17	16	16	16	15	15	15	15	1	1
17	18	18	17	17	17	16	16	16	16	1	1
18	19	19	18	18	18	17	17	17	16	1	1
19	20	20	19	19	19	18	18	18	17	1	1
20	21	21	20	20	20	19	19	19	18	1	1
21	22	22	21	21	21	20	20	20	19	1	1
22	23	23	22	22	22	21	21	21	20	1	1
23	24	24	23	23	23	22	22	21	21	1	1
24	25	25	24	24	24	23	23	22	22	1	1
25	26	26	25	25	25	24	24	23	23	1	1
26	27	27	26	26	26	25	25	24	24	1	1
27	28	28	27	27	27	26	26	25	25	1	1
28	29	29	28	28	28	27	27	26	26	1	1
29	30	30	29	29	29	28	28	27	27	1	1
30	32	31	30	30	30	29	28	28	28	2	1
31	33	32	32	31	30	30	29	29	28	2	1
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35	37	36	36	35	34	34	33	33	32	2	1
36	38	37	37	36	35	35	34	34	33	2	1
37	39	38	38	37	36	36	35	35	34	2	1
38	40	39	39	38	37	37	36	35	35	2	1
39	41	40	40	39	38	38	37	36	36	2	1
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42	44	43	43	42	41	41	40	39	38	2	1
43	45	44	44	43	42	42	41	40	39	2	1
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45	47	47	46	45	44	44	43	42	41	2	2
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47	49	49	48	47	46	45	45	44	43	2	2
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49	51	51	50	49	48	47	47	46	45	2	2
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52	55	54	53	52	51	50	49	49	48	3	2
53	56	55	54	53	52	51	50	49	49	3	2
54	57	56	55	54	53	52	51	50	50	3	2
55	58	57	56	55	54	53	52	51	50	3	2
56	59	58	57	56	55	54	53	52	51	3	2
57	60	59	58	57	56	55	54	53	52	3	2
58	61	60	59	58	57	56	55	54	53	3	2
59	62	61	60	59	58	57	56	55	54	3	2
60	63	62	61	60	59	58	57	56	55	3	2
″	63	62	61	60	59	58	57	56	55	3	2

Proportional Parts

′	*l* sin 9.	d 1′	*l* csc 10.	*l* tan 9.	d 1′	*l* cot 10.	*l* sec 10.	d 1′	*l* cos 9.	′
0	35209	54	64791	36336	58	63664	01128	3	98872	60
1	263	55	737	394	58	606	131	2	869	59
2	318	55	682	452	57	548	133	3	867	58
3	373	54	627	509	57	491	136	3	864	57
4	427	54	573	566	58	434	139	3	861	56
5	481	55	519	624	57	376	142	3	858	55
6	536	54	464	681	57	319	145	3	855	54
7	590	54	410	738	57	262	148	3	852	53
8	644	54	356	795	57	205	151	3	849	52
9	698	54	302	852	57	148	154	3	846	51
10	752	54	248	909	57	091	157	3	843	50
11	806	54	194	966	57	034	160	3	840	49
12	860	54	140	37023	57	62977	163	3	837	48
13	914	54	086	080	57	920	166	3	834	47
14	968	54	032	137	56	863	169	3	831	46
15	36022	53	63978	193	57	807	172	3	828	45
16	075	54	925	250	56	750	175	3	825	44
17	129	53	871	306	57	694	178	3	822	43
18	182	54	818	363	56	637	181	3	819	42
19	236	53	764	419	57	581	184	3	816	41
20	289	53	711	476	56	524	187	3	813	40
21	342	53	658	532	56	468	190	3	810	39
22	395	54	605	588	56	412	193	3	807	38
23	449	53	551	644	56	356	196	3	804	37
24	502	53	498	700	56	300	199	3	801	36
25	555	53	445	756	56	244	202	3	798	35
26	608	52	392	812	56	188	205	3	795	34
27	660	53	340	868	56	132	208	3	792	33
28	713	53	287	924	56	076	211	3	789	32
29	766	53	234	980	55	020	214	3	786	31
30	36819	52	63181	38035	56	61965	01217	3	98783	30
31	871	53	129	091	56	909	220	3	780	29
32	924	52	076	147	55	853	223	3	777	28
33	976	52	024	202	55	798	226	3	774	27
34	37028	53	62972	257	56	743	229	3	771	26
35	081	52	919	313	55	687	232	3	768	25
36	133	52	867	368	55	632	235	3	765	24
37	185	52	815	423	56	577	238	3	762	23
38	237	52	763	479	55	521	241	3	759	22
39	289	52	711	534	55	466	244	3	756	21
40	341	52	659	589	55	411	247	3	753	20
41	393	52	607	644	55	356	250	4	750	19
42	445	52	555	699	55	301	254	3	746	18
43	497	52	503	754	54	246	257	3	743	17
44	549	51	451	808	55	192	260	3	740	16
45	600	52	400	863	55	137	263	3	737	15
46	652	51	348	918	54	082	266	3	734	14
47	703	52	297	972	55	028	269	3	731	13
48	755	51	245	39027	55	60973	272	3	728	12
49	806	52	194	082	54	918	275	3	725	11
50	858	51	142	136	54	864	278	3	722	10
51	909	51	091	190	55	810	281	4	719	9
52	960	51	040	245	54	755	285	3	715	8
53	38011	51	61989	299	54	701	288	3	712	7
54	062	51	938	353	54	647	291	3	709	6
55	113	51	887	407	54	593	294	3	706	5
56	164	51	836	461	54	539	297	3	703	4
57	215	51	785	515	54	485	300	3	700	3
58	266	51	734	569	54	431	303	3	697	2
59	317	51	683	623	54	377	306	4	694	1
60	38368		61632	39677		60323	01310		98690	0
′	9. *l* cos	d 1′	10. *l* sec	9. *l* cot	d 1′	10. *l* tan	10. *l* csc	d 1′	9. *l* sin	′

Proportional Parts

″	58	57	56	55	54	53	52	51	4	3	2
0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	0	0	0
2	2	2	2	2	2	2	2	2	0	0	0
3	3	3	3	3	3	3	3	3	0	0	0
4	4	4	4	4	4	4	3	3	0	0	0
5	5	5	5	5	4	4	4	4	0	0	0
6	6	6	6	6	5	5	5	5	0	0	0
7	7	7	7	6	6	6	6	6	0	0	0
8	8	8	7	7	7	7	7	7	1	0	0
9	9	9	8	8	8	8	8	8	1	0	0
10	10	10	9	9	9	9	9	8	1	0	0
11	11	10	10	10	10	10	10	9	1	1	0
12	12	11	11	11	11	11	10	10	1	1	0
13	13	12	12	12	12	11	11	11	1	1	0
14	14	13	13	13	13	12	12	12	1	1	0
15	14	14	14	14	14	13	13	13	1	1	0
16	15	15	15	15	14	14	14	14	1	1	1
17	16	16	16	16	15	15	15	14	1	1	1
18	17	17	17	16	16	16	16	15	1	1	1
19	18	18	18	17	17	17	16	16	1	1	1
20	19	19	19	18	18	18	17	17	1	1	1
21	20	20	20	19	19	19	18	18	1	1	1
22	21	21	21	20	20	19	19	19	1	1	1
23	22	22	21	21	21	20	20	20	2	1	1
24	23	23	22	22	22	21	21	20	2	1	1
25	24	24	23	23	22	22	22	21	2	1	1
26	25	25	24	24	23	23	23	22	2	1	1
27	26	26	25	25	24	24	23	23	2	1	1
28	27	27	26	26	25	25	24	24	2	1	1
29	28	28	27	27	26	26	25	25	2	1	1
30	29	28	28	28	27	26	26	26	2	2	1
31	30	29	29	28	28	27	27	26	2	2	1
32	31	30	30	29	29	28	28	27	2	2	1
33	32	31	31	30	30	29	29	28	2	2	1
34	33	32	32	31	31	30	29	29	2	2	1
35	34	33	33	32	32	31	30	30	2	2	1
36	35	34	34	33	32	32	31	31	2	2	1
37	36	35	35	34	33	33	32	31	2	2	1
38	37	36	35	35	34	34	33	32	3	2	1
39	38	37	36	36	35	34	34	33	3	2	1
40	39	38	37	37	36	35	35	34	3	2	1
41	40	39	38	38	37	36	36	35	3	2	1
42	41	40	39	38	38	37	36	36	3	2	1
43	42	41	40	39	39	38	37	37	3	2	1
44	43	42	41	40	40	39	38	37	3	2	1
45	44	43	42	41	40	40	39	38	3	2	2
46	44	44	43	42	41	41	40	39	3	2	2
47	45	45	44	43	42	42	41	40	3	2	2
48	46	46	45	44	43	42	42	41	3	2	2
49	47	47	46	45	44	43	42	42	3	2	2
50	48	48	47	46	45	44	43	42	3	2	2
51	49	48	48	47	46	45	44	43	3	3	2
52	50	49	49	48	47	46	45	44	3	3	2
53	51	50	49	49	48	47	46	45	4	3	2
54	52	51	50	50	49	48	47	46	4	3	2
55	53	52	51	50	50	49	48	47	4	3	2
56	54	53	52	51	50	49	49	48	4	3	2
57	55	54	53	52	51	50	49	48	4	3	2
58	56	55	54	53	52	51	50	49	4	3	2
59	57	56	55	54	53	52	51	50	4	3	2
60	58	57	56	55	54	53	52	51	4	3	2
″	58	57	56	55	54	53	52	51	4	3	2

Proportional Parts

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	38368		61632	39677		60323	01310		98690	60
1	418	50	582	731	54	269	313	3	687	59
2	469	51	531	785	54	215	316	3	684	58
3	519	50	481	838	53	162	319	3	681	57
4	570	51	430	892	54	108	322	3	678	56
5	620	50	380	945	53	055	325	3	675	55
6	670	50	330	999	54	001	329	4	671	54
7	721	51	279	40052	53	59948	332	3	668	53
8	771	50	229	106	54	894	335	3	665	52
9	821	50	179	159	53	841	338	3	662	51
10	871	50	129	212	53	788	341	3	659	50
11	921	50	079	266	54	734	344	3	656	49
12	971	50	029	319	53	681	348	4	652	48
13	39021	50	60979	372	53	628	351	3	649	47
14	071	50	929	425	53	575	354	3	646	46
15	121	50	879	478	53	522	357	3	643	45
16	170	49	830	531	53	469	360	3	640	44
17	220	50	780	584	53	416	364	4	636	43
18	270	50	730	636	52	364	367	3	633	42
19	319	49	681	689	53	311	370	3	630	41
20	369	50	631	742	53	258	373	3	627	40
21	418	49	582	795	53	205	377	4	623	39
22	467	49	533	847	52	153	380	3	620	38
23	517	50	483	900	53	100	383	3	617	37
24	566	49	434	952	52	048	386	3	614	36
25	615	49	385	41005	53	58995	390	4	610	35
26	664	49	336	057	52	943	393	3	607	34
27	713	49	287	109	52	891	396	3	604	33
28	762	49	238	161	52	839	399	3	601	32
29	811	49	189	214	53	786	403	4	597	31
30	39860	49	60140	41266	52	58734	01406	3	98594	30
31	909	49	091	318	52	682	409	3	591	29
32	958	49	042	370	52	630	412	3	588	28
33	40006	48	59994	422	52	578	416	4	584	27
34	055	49	945	474	52	526	419	3	581	26
35	103	48	897	526	52	474	422	3	578	25
36	152	49	848	578	52	422	426	4	574	24
37	200	48	800	629	51	371	429	3	571	23
38	249	49	751	681	52	319	432	3	568	22
39	297	48	703	733	52	267	435	3	565	21
40	346	49	654	784	51	216	439	4	561	20
41	394	48	606	836	52	164	442	3	558	19
42	442	48	558	887	51	113	445	3	555	18
43	490	48	510	939	52	061	449	4	551	17
44	538	48	462	990	51	010	452	3	548	16
45	586	48	414	42041	51	57959	455	3	545	15
46	634	48	366	093	52	907	459	4	541	14
47	682	48	318	144	51	856	462	3	538	13
48	730	48	270	195	51	805	465	3	535	12
49	778	48	222	246	51	754	469	4	531	11
50	825	47	175	297	51	703	472	3	528	10
51	873	48	127	348	51	652	475	3	525	9
52	921	48	079	399	51	601	479	4	521	8
53	968	47	032	450	51	550	482	3	518	7
54	41016	48	58984	501	51	499	485	3	515	6
55	063	47	937	552	51	448	489	4	511	5
56	111	48	889	603	51	397	492	3	508	4
57	158	47	842	653	50	347	495	3	505	3
58	205	47	795	704	51	296	499	4	501	2
59	252	47	748	755	51	245	502	3	498	1
60	41300	48	58700	42805	50	57195	01506	4	98494	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	54	53	52	51	50	49	48	47	4	3
	Proportional Parts									
0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	0	0
2	2	2	2	2	2	2	2	2	0	0
3	3	3	3	3	2	2	2	2	0	0
4	4	4	3	3	3	3	3	3	0	0
5	4	4	4	4	4	4	4	4	0	0
6	5	5	5	5	5	5	5	5	0	0
7	6	6	6	6	6	6	6	5	0	0
8	7	7	7	7	7	7	6	6	1	0
9	8	8	8	8	8	7	7	7	1	0
10	9	9	9	8	8	8	8	8	1	0
11	10	10	10	9	9	9	9	9	1	1
12	11	11	10	10	10	10	10	9	1	1
13	12	11	11	11	11	11	10	10	1	1
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18	16	16	16	15	15	15	14	14	1	1
19	17	17	16	16	16	16	15	15	1	1
20	18	18	17	17	17	16	16	16	1	1
21	19	19	18	18	18	17	17	16	1	1
22	20	19	19	19	18	18	18	17	1	1
23	21	20	20	20	19	19	18	18	2	1
24	22	21	21	20	20	20	19	19	2	1
25	22	22	22	21	21	20	20	20	2	1
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43	39	38	37	37	36	35	34	34	3	2
44	40	39	38	37	37	36	35	34	3	2
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54	49	48	47	46	45	44	43	42	4	3
55	50	49	48	47	46	45	44	43	4	3
56	50	49	49	48	47	46	45	44	4	3
57	51	50	49	48	48	47	46	45	4	3
58	52	51	50	49	48	47	46	45	4	3
59	53	52	51	50	49	48	47	46	4	3
60	54	53	52	51	50	49	48	47	4	3
″	54	53	52	51	50	49	48	47	4	3
	Proportional Parts									

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	41300	47	58700	42805	51	57195	01506	3	98494	60
1	347	47	653	856	50	144	509	3	491	59
2	394	47	606	906	51	094	512	4	488	58
3	441	47	559	957	50	043	516	3	484	57
4	488	47	512	43007	50	56993	519	4	481	56
5	535	47	465	057	51	943	523	3	477	55
6	582	46	418	108	50	892	526	3	474	54
7	628	47	372	158	50	842	529	4	471	53
8	675	47	325	208	50	792	533	3	467	52
9	722	46	278	258	50	742	536	4	464	51
10	768	47	232	308	50	692	540	3	460	50
11	815	46	185	358	50	642	543	4	457	49
12	861	47	139	408	50	592	547	3	453	48
13	908	46	092	458	50	542	550	3	450	47
14	954	47	046	508	50	492	553	4	447	46
15	42001	46	57999	558	49	442	557	3	443	45
16	047	46	953	607	50	393	560	4	440	44
17	093	47	907	657	50	343	564	3	436	43
18	140	46	860	707	49	293	567	4	433	42
19	186	46	814	756	50	244	571	3	429	41
20	232	46	768	806	49	194	574	4	426	40
21	278	46	722	855	50	145	578	3	422	39
22	324	46	676	905	49	095	581	4	419	38
23	370	46	630	954	50	046	585	3	415	37
24	416	45	584	44004	49	55996	588	3	412	36
25	461	46	539	053	49	947	591	4	409	35
26	507	46	493	102	49	898	595	3	405	34
27	553	46	447	151	50	849	598	4	402	33
28	599	45	401	201	49	799	602	3	398	32
29	644	46	356	250	49	750	605	4	395	31
30	42690	45	57310	44299	49	55701	01609	3	98391	30
31	735	46	265	348	49	652	612	4	388	29
32	781	45	219	397	49	603	616	3	384	28
33	826	46	174	446	49	554	619	4	381	27
34	872	45	128	495	49	505	623	4	377	26
35	917	45	083	544	48	456	627	3	373	25
36	962	46	038	592	49	408	630	4	370	24
37	43008	45	56992	641	49	359	634	3	366	23
38	053	45	947	690	48	310	637	4	363	22
39	098	45	902	738	49	262	641	3	359	21
40	143	45	857	787	49	213	644	4	356	20
41	188	45	812	836	48	164	648	3	352	19
42	233	45	767	884	49	116	651	4	349	18
43	278	45	722	933	48	067	655	3	345	17
44	323	44	677	981	48	019	658	4	342	16
45	367	45	633	45029	49	54971	662	4	338	15
46	412	45	588	078	48	922	666	3	334	14
47	457	45	543	126	48	874	669	4	331	13
48	502	44	498	174	48	826	673	3	327	12
49	546	45	454	222	49	778	676	4	324	11
50	591	44	409	271	48	729	680	3	320	10
51	635	45	365	319	48	681	683	4	317	9
52	680	44	320	367	48	633	687	4	313	8
53	724	45	276	415	48	585	691	3	309	7
54	769	44	231	463	48	537	694	4	306	6
55	813	44	187	511	48	489	698	3	302	5
56	857	44	143	559	47	441	701	4	299	4
57	901	45	099	606	48	394	705	4	295	3
58	946	44	054	654	48	346	709	3	291	2
59	990	44	010	702	48	298	712	4	288	1
60	44034		55966	45750		54250	01716		98284	0
′	l cos 9.	d 1′	l sec 10.	l cot 9.	d 1′	l tan 10.	l csc 10.	d 1′	l sin 9.	′

Proportional Parts										
″	51	50	49	48	47	46	45	44	4	3
0	0	0	0	0	0	0	0	0	0	0
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3	3	2	2	2	2	2	2	2	0	0
4	3	3	3	3	3	3	3	3	0	0
5	4	4	4	4	4	4	4	4	0	0
6	5	5	5	5	5	5	4	4	0	0
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8	7	7	7	6	6	6	6	6	1	0
9	8	8	7	7	7	7	7	7	1	0
10	8	8	8	8	8	8	8	7	1	0
11	9	9	9	9	9	8	8	8	1	1
12	10	10	10	10	9	9	9	9	1	1
13	11	11	11	10	10	10	10	10	1	1
14	12	12	11	11	11	11	10	10	1	1
15	13	12	12	12	12	12	11	11	1	1
16	14	13	13	13	13	12	12	12	1	1
17	14	14	14	14	13	13	13	12	1	1
18	15	15	15	14	14	14	14	13	1	1
19	16	16	16	15	15	15	14	14	1	1
20	17	17	16	16	16	15	15	15	1	1
21	18	18	17	17	16	16	16	15	1	1
22	19	18	18	18	17	17	16	16	1	1
23	20	19	19	18	18	18	17	17	2	1
24	20	20	20	19	19	18	18	18	2	1
25	21	21	20	20	20	19	19	18	2	1
26	22	22	21	21	20	20	20	19	2	1
27	23	22	22	22	21	21	20	20	2	1
28	24	23	23	22	22	21	21	21	2	1
29	25	24	24	23	23	22	22	21	2	1
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36	31	30	29	29	28	28	27	26	2	2
37	31	31	30	30	29	28	28	27	2	2
38	32	32	31	30	30	29	28	28	3	2
39	33	33	32	31	31	30	29	29	3	2
40	34	33	33	32	31	31	30	29	3	2
41	35	34	33	33	32	31	31	30	3	2
42	36	35	34	34	33	32	32	31	3	2
43	37	36	35	34	34	33	32	32	3	2
44	37	37	36	35	34	34	33	32	3	2
45	38	38	37	36	35	34	34	33	3	2
46	39	38	38	37	36	35	34	34	3	2
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48	41	40	39	38	38	37	36	35	3	2
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50	42	42	41	40	39	38	38	37	3	2
51	43	42	42	41	40	39	38	37	3	3
52	44	43	42	42	41	40	39	38	3	3
53	45	44	43	42	42	41	40	39	4	3
54	46	45	44	43	42	41	40	40	4	3
55	47	46	45	44	43	42	41	40	4	3
56	48	47	46	45	44	43	42	41	4	3
57	48	48	47	46	45	44	43	42	4	3
58	49	48	47	46	45	44	44	43	4	3
59	50	49	48	47	46	45	44	43	4	3
60	51	50	49	48	47	46	45	44	4	3
″	51	50	49	48	47	46	45	44	4	3
Proportional Parts										

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	44034	44	55966	45750	47	54250	01716	3	98284	60
1	078	44	922	797	48	203	719	4	281	59
2	122	44	878	845	47	155	723	4	277	58
3	166	44	834	892	48	108	727	3	273	57
4	210	43	790	940	47	060	730	4	270	56
5	253	44	747	987	48	013	734	4	266	55
6	297	44	703	46035	47	53965	738	3	262	54
7	341	44	659	082	48	918	741	4	259	53
8	385	43	615	130	47	870	745	4	255	52
9	428	44	572	177	47	823	749	3	251	51
10	472	44	528	224	47	776	752	4	248	50
11	516	43	484	271	48	729	756	4	244	49
12	559	43	441	319	47	681	760	3	240	48
13	602	44	398	366	47	634	763	4	237	47
14	646	43	354	413	47	587	767	4	233	46
15	689	44	311	460	47	540	771	3	229	45
16	733	43	267	507	47	493	774	4	226	44
17	776	43	224	554	47	446	778	4	222	43
18	819	43	181	601	47	399	782	3	218	42
19	862	43	138	648	46	352	785	4	215	41
20	905	43	095	694	47	306	789	4	211	40
21	948	44	052	741	47	259	793	3	207	39
22	992	43	008	788	47	212	796	4	204	38
23	45035	42	54965	835	46	165	800	4	200	37
24	077	43	923	881	47	119	804	4	196	36
25	120	43	880	928	47	072	808	3	192	35
26	163	43	837	975	46	025	811	4	189	34
27	206	43	794	47021	47	52979	815	4	185	33
28	249	43	751	068	46	932	819	4	181	32
29	292	42	708	114	46	886	823	3	177	31
30	45334	43	54666	47160	47	52840	01826	4	98174	30
31	377	42	623	207	46	793	830	4	170	29
32	419	43	581	253	46	747	834	4	166	28
33	462	42	538	299	47	701	838	3	162	27
34	504	43	496	346	46	654	841	4	159	26
35	547	42	453	392	46	608	845	4	155	25
36	589	43	411	438	46	562	849	4	151	24
37	632	42	368	484	46	516	853	3	147	23
38	674	42	326	530	46	470	856	4	144	22
39	716	42	284	576	46	424	860	4	140	21
40	758	43	242	622	46	378	864	4	136	20
41	801	42	199	668	46	332	868	3	132	19
42	843	42	157	714	46	286	871	4	129	18
43	885	42	115	760	46	240	875	4	125	17
44	927	42	073	806	46	194	879	4	121	16
45	969	42	031	852	45	148	883	4	117	15
46	46011	42	53989	897	46	103	887	3	113	14
47	053	42	947	943	46	057	890	4	110	13
48	095	41	905	989	46	011	894	4	106	12
49	136	42	864	48035	45	51965	898	4	102	11
50	178	42	822	080	46	920	902	4	098	10
51	220	42	780	126	45	874	906	4	094	9
52	262	41	738	171	46	829	910	3	090	8
53	303	42	697	217	45	783	913	4	087	7
54	345	41	655	262	45	738	917	4	083	6
55	386	42	614	307	46	693	921	4	079	5
56	428	41	572	353	45	647	925	4	075	4
57	469	42	531	398	45	602	929	4	071	3
58	511	41	489	443	46	557	933	4	067	2
59	552	42	448	489	45	511	937	3	063	1
60	46594		53406	48534		51466	01940		98060	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts 48	47	46	45	44	43	42	41	4	3
0	0	0	0	0	0	0	0	0	0	0
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3	2	2	2	2	2	2	2	2	0	0
4	3	3	3	3	3	3	3	3	0	0
5	4	4	4	4	4	4	4	3	0	0
6	5	5	5	4	4	4	4	4	0	0
7	6	5	5	5	5	5	5	5	0	0
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9	7	7	7	7	7	6	6	6	1	0
10	8	8	8	8	7	7	7	7	1	0
11	9	9	8	8	8	8	8	8	1	1
12	10	9	9	9	9	9	8	8	1	1
13	10	10	10	10	10	9	9	9	1	1
14	11	11	11	10	10	10	10	10	1	1
15	12	12	12	11	11	11	10	10	1	1
16	13	13	12	12	12	11	11	11	1	1
17	14	13	13	13	12	12	12	12	1	1
18	14	14	14	14	13	13	13	12	1	1
19	15	15	15	14	14	14	13	13	1	1
20	16	16	15	15	15	14	14	14	1	1
21	17	16	16	16	15	15	15	14	1	1
22	18	17	17	16	16	16	15	15	1	1
23	18	18	18	17	17	16	16	16	2	1
24	19	19	18	18	18	17	17	16	2	1
25	20	20	19	19	18	18	18	17	2	1
26	21	20	20	20	19	19	18	18	2	1
27	22	21	21	20	20	19	19	18	2	1
28	22	22	21	21	21	20	20	19	2	1
29	23	23	22	22	21	21	20	20	2	1
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31	25	24	24	23	23	22	22	21	2	2
32	26	25	25	24	23	23	22	22	2	2
33	26	26	25	25	24	24	23	23	2	2
34	27	27	26	26	25	24	24	23	2	2
35	28	27	27	26	26	25	24	24	2	2
36	29	28	28	27	26	26	25	25	2	2
37	30	29	28	28	27	27	26	25	2	2
38	30	30	29	28	28	27	27	26	3	2
39	31	31	30	29	29	28	27	27	3	2
40	32	31	31	30	29	29	28	27	3	2
41	33	32	31	31	30	29	29	28	3	2
42	34	33	32	32	31	30	29	29	3	2
43	34	34	33	32	32	31	30	29	3	2
44	35	34	34	33	32	32	31	30	3	2
45	36	35	34	34	33	32	32	31	3	2
46	37	36	35	34	34	33	32	31	3	2
47	38	37	36	35	34	34	33	32	3	2
48	38	38	37	36	35	34	34	33	3	2
49	39	38	38	37	36	35	34	33	3	2
50	40	39	38	38	37	36	35	34	3	2
51	41	40	39	38	38	37	36	35	3	3
52	42	41	40	39	38	37	36	36	3	3
53	42	42	41	40	39	38	37	36	4	3
54	43	42	41	40	40	39	38	37	4	3
55	44	43	42	41	40	39	38	38	4	3
56	45	44	43	42	41	40	39	38	4	3
57	46	45	44	43	42	41	40	39	4	3
58	46	45	44	44	43	42	41	40	4	3
59	47	46	45	44	43	42	41	40	4	3
60	48	47	46	45	44	43	42	41	4	3
″	48 Proportional Parts	47	46	45	44	43	42	41	4	3

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	46594	41	53406	48534	45	51466	01940	4	98060	60
1	635	41	365	579	45	421	944	4	056	59
2	676	41	324	624	45	376	948	4	052	58
3	717	41	283	669	45	331	952	4	048	57
4	758	42	242	714	45	286	956	4	044	56
5	800	41	200	759	45	241	960	4	040	55
6	841	41	159	804	45	196	964	4	036	54
7	882	41	118	849	45	151	968	3	032	53
8	923	41	077	894	45	106	971	4	029	52
9	964	41	036	939	45	061	975	4	025	51
10	47005	40	52995	984	45	016	979	4	021	50
11	045	41	955	49029	44	50971	983	4	017	49
12	086	41	914	073	45	927	987	4	013	48
13	127	41	873	118	45	882	991	4	009	47
14	168	41	832	163	44	837	995	4	005	46
15	209	40	791	207	45	793	999	4	001	45
16	249	41	751	252	44	748	02003	4	97997	44
17	290	40	710	296	45	704	007	4	993	43
18	330	41	670	341	44	659	011	3	989	42
19	371	40	629	385	45	615	014	4	986	41
20	411	41	589	430	44	570	018	4	982	40
21	452	40	548	474	45	526	022	4	978	39
22	492	41	508	519	44	481	026	4	974	38
23	533	40	467	563	44	437	030	4	970	37
24	573	40	427	607	45	393	034	4	966	36
25	613	41	387	652	44	348	038	4	962	35
26	654	40	346	696	44	304	042	4	958	34
27	694	40	306	740	44	260	046	4	954	33
28	734	40	266	784	44	216	050	4	950	32
29	774	40	226	828	44	172	054	4	946	31
30	47814	40	52186	49872	44	50128	02058	4	97942	30
31	854	40	146	916	44	084	062	4	938	29
32	894	40	106	960	44	040	066	4	934	28
33	934	40	066	50004	44	49996	070	4	930	27
34	974	40	026	048	44	952	074	4	926	26
35	48014	40	51986	092	44	908	078	4	922	25
36	054	40	946	136	44	864	082	4	918	24
37	094	39	906	180	43	820	086	4	914	23
38	133	40	867	223	44	777	090	4	910	22
39	173	40	827	267	44	733	094	4	906	21
40	213	39	787	311	44	689	098	4	902	20
41	252	40	748	355	43	645	102	4	898	19
42	292	40	708	398	44	602	106	4	894	18
43	332	39	668	442	43	558	110	4	890	17
44	371	40	629	485	44	515	114	4	886	16
45	411	39	589	529	43	471	118	4	882	15
46	450	40	550	572	44	428	122	4	878	14
47	490	39	510	616	43	384	126	4	874	13
48	529	39	471	659	44	341	130	4	870	12
49	568	39	432	703	43	297	134	5	866	11
50	607	40	393	746	43	254	139	4	861	10
51	647	39	353	789	44	211	143	4	857	9
52	686	39	314	833	43	167	147	4	853	8
53	725	39	275	876	43	124	151	4	849	7
54	764	39	236	919	43	081	155	4	845	6
55	803	39	197	962	43	038	159	4	841	5
56	842	39	158	51005	43	48995	163	4	837	4
57	881	39	119	048	44	952	167	4	833	3
58	920	39	080	092	43	908	171	4	829	2
59	959	39	041	135	43	865	175	4	825	1
60	48998		51002	51178		48822	02179		97821	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

Proportional Parts										
″	45	44	43	42	41	40	39	5	4	3
0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	0	0	0
2	2	1	1	1	1	1	1	0	0	0
3	2	2	2	2	2	2	2	0	0	0
4	3	3	3	3	3	3	3	0	0	0
5	4	4	4	4	3	3	3	0	0	0
6	4	4	4	4	4	4	4	0	0	0
7	5	5	5	5	5	5	5	1	0	0
8	6	6	6	6	5	5	5	1	1	0
9	7	7	6	6	6	6	6	1	1	0
10	8	7	7	7	7	7	6	1	1	0
11	8	8	8	8	7	7	7	1	1	1
12	9	9	9	8	8	8	8	1	1	1
13	10	10	9	9	9	9	8	1	1	1
14	10	10	10	10	10	9	9	1	1	1
15	11	11	11	10	10	10	10	1	1	1
16	12	12	11	11	11	11	10	1	1	1
17	13	12	12	12	12	11	11	1	1	1
18	14	13	13	13	12	12	12	2	1	1
19	14	14	14	13	13	13	12	2	1	1
20	15	15	14	14	14	13	13	2	1	1
21	16	15	15	15	14	14	14	2	1	1
22	16	16	16	15	15	15	14	2	1	1
23	17	17	16	16	16	15	15	2	2	1
24	18	18	17	17	16	16	16	2	2	1
25	19	18	18	18	17	17	16	2	2	1
26	20	19	19	18	18	17	17	2	2	1
27	20	20	19	19	18	18	18	2	2	1
28	21	21	20	20	19	19	18	2	2	1
29	22	21	21	20	20	19	19	2	2	1
30	22	22	22	21	20	20	20	2	2	2
31	23	23	22	22	21	21	20	3	2	2
32	24	23	23	22	22	21	21	3	2	2
33	25	24	24	23	23	22	21	3	2	2
34	26	25	24	24	23	23	22	3	2	2
35	26	26	25	24	24	23	23	3	2	2
36	27	26	26	25	25	24	23	3	2	2
37	28	27	27	26	25	25	24	3	2	2
38	28	28	27	27	26	25	25	3	3	2
39	29	29	28	27	27	26	25	3	3	2
40	30	29	29	28	27	27	26	3	3	2
41	31	30	29	29	28	27	27	3	3	2
42	32	31	30	29	29	28	27	4	3	2
43	32	32	31	30	29	29	28	4	3	2
44	33	32	32	31	30	29	29	4	3	2
45	34	33	32	32	31	30	29	4	3	2
46	34	34	33	32	31	31	30	4	3	2
47	35	34	34	33	32	31	31	4	3	2
48	36	35	34	34	33	32	31	4	3	2
49	37	36	35	34	33	33	32	4	3	2
50	38	37	36	35	34	33	32	4	3	2
51	38	37	37	36	35	34	33	4	3	3
52	39	38	37	36	36	35	34	4	3	3
53	40	39	38	37	36	35	34	4	4	3
54	40	40	39	38	37	36	35	4	4	3
55	41	40	39	38	38	37	36	5	4	3
56	42	41	40	39	38	37	36	5	4	3
57	43	42	41	40	39	38	37	5	4	3
58	44	43	42	41	40	39	38	5	4	3
59	44	43	42	41	40	39	38	5	4	3
60	45	44	43	42	41	40	39	5	4	3
″	45	44	43	42	41	40	39	5	4	3
Proportional Parts										

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	48998	39	51002	51178	43	48822	02179	4	97821	60
1	49037	39	50963	221	43	779	183	5	817	59
2	076	39	924	264	42	736	188	4	812	58
3	115	38	885	306	43	694	192	4	808	57
4	153	39	847	349	43	651	196	4	804	56
5	192	39	808	392	43	608	200	4	800	55
6	231	38	769	435	43	565	204	4	796	54
7	269	39	731	478	42	522	208	4	792	53
8	308	39	692	520	43	480	212	4	788	52
9	347	38	653	563	43	437	216	5	784	51
10	385	39	615	606	42	394	221	4	779	50
11	424	38	576	648	43	352	225	4	775	49
12	462	38	538	691	43	309	229	4	771	48
13	500	39	500	734	42	266	233	4	767	47
14	539	38	461	776	43	224	237	4	763	46
15	577	38	423	819	42	181	241	5	759	45
16	615	39	385	861	42	139	246	4	754	44
17	654	38	346	903	43	097	250	4	750	43
18	692	38	308	946	42	054	254	4	746	42
19	730	38	270	988	43	012	258	4	742	41
20	768	38	232	52031	42	47969	262	4	738	40
21	806	38	194	073	42	927	266	5	734	39
22	844	38	156	115	42	885	271	4	729	38
23	882	38	118	157	43	843	275	4	725	37
24	920	38	080	200	42	800	279	4	721	36
25	958	38	042	242	42	758	283	4	717	35
26	996	38	004	284	42	716	287	5	713	34
27	50034	38	49966	326	42	674	292	4	708	33
28	072	38	928	368	42	632	296	4	704	32
29	110	38	890	410	42	590	300	4	700	31
30	50148	37	49852	52452	42	47548	02304	5	97696	30
31	185	38	815	494	42	506	309	4	691	29
32	223	38	777	536	42	464	313	4	687	28
33	261	37	739	578	42	422	317	4	683	27
34	298	38	702	620	41	380	321	5	679	26
35	336	38	664	661	42	339	326	4	674	25
36	374	37	626	703	42	297	330	4	670	24
37	411	38	589	745	42	255	334	4	666	23
38	449	37	551	787	42	213	338	5	662	22
39	486	37	514	829	41	171	343	4	657	21
40	523	38	477	870	42	130	347	4	653	20
41	561	37	439	912	41	088	351	4	649	19
42	598	37	402	953	42	047	355	5	645	18
43	635	38	365	995	42	005	360	4	640	17
44	673	37	327	53037	41	46963	364	4	636	16
45	710	37	290	078	42	922	368	4	632	15
46	747	37	253	120	41	880	372	5	628	14
47	784	37	216	161	41	839	377	4	623	13
48	821	37	179	202	42	798	381	4	619	12
49	858	38	142	244	41	756	385	5	615	11
50	896	37	104	285	42	715	390	4	610	10
51	933	37	067	327	41	673	394	4	606	9
52	970	37	030	368	41	632	398	5	602	8
53	51007	36	48993	409	41	591	403	4	597	7
54	043	37	957	450	42	550	407	4	593	6
55	080	37	920	492	41	508	411	5	589	5
56	117	37	883	533	41	467	416	4	584	4
57	154	37	846	574	41	426	420	4	580	3
58	191	36	809	615	41	385	424	5	576	2
59	227	37	773	656	41	344	429	4	571	1
60	51264		48736	53697		46303	02433		97567	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

Proportional Parts

″	43	42	41	39	38	37	36	5	4
0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	0	0
2	1	1	1	1	1	1	1	0	0
3	2	2	2	2	2	2	2	0	0
4	3	3	3	3	3	2	2	0	0
5	4	4	3	3	3	3	3	0	0
6	4	4	4	4	4	4	4	0	0
7	5	5	5	5	4	4	4	1	0
8	6	6	5	5	5	5	5	1	1
9	6	6	6	6	6	6	5	1	1
10	7	7	7	6	6	6	6	1	1
11	8	8	8	7	7	7	7	1	1
12	9	8	8	8	8	7	7	1	1
13	9	9	9	8	8	8	8	1	1
14	10	10	10	9	9	9	8	1	1
15	11	10	10	10	10	9	9	1	1
16	11	11	11	10	10	10	10	1	1
17	12	12	12	11	11	10	10	1	1
18	13	13	12	12	11	11	11	2	1
19	14	13	13	12	12	12	11	2	1
20	14	14	14	13	13	12	12	2	1
21	15	15	14	14	13	13	13	2	1
22	16	15	15	14	14	14	13	2	1
23	16	16	16	15	15	14	14	2	2
24	17	17	16	16	15	15	14	2	2
25	18	18	17	16	16	15	15	2	2
26	19	18	18	17	16	16	16	2	2
27	19	19	18	18	17	17	16	2	2
28	20	20	19	18	18	17	17	2	2
29	21	20	20	19	18	18	17	2	2
30	22	21	20	20	19	18	18	2	2
31	22	22	21	20	20	19	19	3	2
32	23	22	22	21	20	20	19	3	2
33	24	23	23	21	21	20	20	3	2
34	24	24	23	22	22	21	20	3	2
35	25	24	24	23	22	22	21	3	2
36	26	25	25	23	23	22	22	3	2
37	27	26	25	24	23	23	22	3	2
38	27	27	26	25	24	23	23	3	3
39	28	27	27	25	25	24	23	3	3
40	29	28	27	26	25	25	24	3	3
41	29	29	28	27	26	25	25	3	3
42	30	29	29	27	27	26	25	4	3
43	31	30	29	28	27	27	26	4	3
44	32	31	30	29	28	27	26	4	3
45	32	32	31	29	28	28	27	4	3
46	33	32	31	30	29	28	28	4	3
47	34	33	32	31	30	29	28	4	3
48	34	34	33	31	30	30	29	4	3
49	35	34	33	32	31	30	29	4	3
50	36	35	34	32	32	31	30	4	3
51	37	36	35	33	32	31	31	4	3
52	37	36	36	34	33	32	31	4	3
53	38	37	36	34	34	33	32	4	4
54	39	38	37	35	34	33	32	4	4
55	39	38	38	36	35	34	33	5	4
56	40	39	38	36	35	35	34	5	4
57	41	40	39	37	36	35	34	5	4
58	42	41	40	38	37	36	35	5	4
59	42	41	40	38	37	36	35	5	4
60	43	42	41	39	38	37	36	5	4
″	43	42	41	39	38	37	36	5	4

Proportional Parts

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	51264	37	48736	53697	41	46303	02433	4	97567	60
1	301	37	699	738	41	262	437	5	563	59
2	338	36	662	779	41	221	442	4	558	58
3	374	37	626	820	41	180	446	4	554	57
4	411	36	589	861	41	139	450	5	550	56
5	447	37	553	902	41	098	455	4	545	55
6	484	36	516	943	41	057	459	5	541	54
7	520	37	480	984	41	016	464	4	536	53
8	557	36	443	54025	40	45975	468	4	532	52
9	593	36	407	065	41	935	472	5	528	51
10	629	37	371	106	41	894	477	4	523	50
11	666	36	334	147	40	853	481	4	519	49
12	702	36	298	187	41	813	485	5	515	48
13	738	36	262	228	41	772	490	4	510	47
14	774	37	226	269	40	731	494	5	506	46
15	811	36	189	309	41	691	499	4	501	45
16	847	36	153	350	40	650	503	5	497	44
17	883	36	117	390	41	610	508	4	492	43
18	919	36	081	431	40	569	512	4	488	42
19	955	36	045	471	41	529	516	5	484	41
20	991	36	009	512	40	488	521	4	479	40
21	52027	36	47973	552	41	448	525	5	475	39
22	063	36	937	593	40	407	530	4	470	38
23	099	36	901	633	40	367	534	5	466	37
24	135	36	865	673	41	327	539	4	461	36
25	171	36	829	714	40	286	543	4	457	35
26	207	35	793	754	40	246	547	5	453	34
27	242	36	758	794	41	206	552	4	448	33
28	278	36	722	835	40	165	556	5	444	32
29	314	36	686	875	40	125	561	4	439	31
30	52350	35	47650	54915	40	45085	02565	5	97435	30
31	385	36	615	955	40	045	570	4	430	29
32	421	35	579	995	40	005	574	5	426	28
33	456	36	544	55035	40	44965	579	4	421	27
34	492	35	508	075	40	925	583	5	417	26
35	527	36	473	115	40	885	588	4	412	25
36	563	35	437	155	40	845	592	5	408	24
37	598	36	402	195	40	805	597	4	403	23
38	634	35	366	235	40	765	601	5	399	22
39	669	36	331	275	40	725	606	4	394	21
40	705	35	295	315	40	685	610	5	390	20
41	740	35	260	355	40	645	615	4	385	19
42	775	36	225	395	39	605	619	5	381	18
43	811	35	189	434	40	566	624	4	376	17
44	846	35	154	474	40	526	628	5	372	16
45	881	35	119	514	40	486	633	4	367	15
46	916	35	084	554	39	446	637	5	363	14
47	951	35	049	593	40	407	642	5	358	13
48	986	35	014	633	40	367	647	4	353	12
49	53021	35	46979	673	39	327	651	5	349	11
50	056	36	944	712	40	288	656	4	344	10
51	092	34	908	752	39	248	660	5	340	9
52	126	35	874	791	40	209	665	4	335	8
53	161	35	839	831	39	169	669	5	331	7
54	196	35	804	870	40	130	674	4	326	6
55	231	35	769	910	39	090	678	5	322	5
56	266	35	734	949	40	051	683	5	317	4
57	301	35	699	989	39	011	688	4	312	3
58	336	34	664	56028	39	43972	692	5	308	2
59	370	35	630	067	40	933	697	4	303	1
60	53405		46595	56107		43893	02701		97299	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

Proportional Parts

″	41	40	39	37	36	35	34	5	4
0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	0	0
2	1	1	1	1	1	1	1	0	0
3	2	2	2	2	2	2	2	0	0
4	3	3	3	2	2	2	2	0	0
5	3	3	3	3	3	3	3	0	0
6	4	4	4	4	4	4	3	0	0
7	5	5	5	4	4	4	4	1	0
8	5	5	5	5	5	5	5	1	1
9	6	6	6	6	5	5	5	1	1
10	7	7	6	6	6	6	6	1	1
11	8	7	7	7	7	6	6	1	1
12	8	8	8	7	7	7	7	1	1
13	9	9	8	8	8	8	7	1	1
14	10	9	9	9	8	8	8	1	1
15	10	10	10	9	9	9	8	1	1
16	11	11	10	10	10	9	9	1	1
17	12	11	11	10	10	10	10	1	1
18	12	12	12	11	11	10	10	2	1
19	13	13	12	12	11	11	11	2	1
20	14	13	13	12	12	12	11	2	1
21	14	14	14	13	13	12	12	2	1
22	15	15	14	14	13	13	12	2	1
23	16	15	15	14	14	13	13	2	2
24	16	16	16	15	14	14	14	2	2
25	17	17	16	15	15	15	14	2	2
26	18	17	17	16	16	15	15	2	2
27	18	18	18	17	16	16	15	2	2
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29	20	19	19	18	17	17	16	2	2
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32	22	21	21	20	19	19	18	3	2
33	23	22	21	20	20	19	19	3	2
34	23	23	22	21	20	20	19	3	2
35	24	23	23	22	21	20	20	3	2
36	25	24	23	22	22	21	20	3	2
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42	29	28	27	26	25	24	24	4	3
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50	34	33	32	31	30	29	28	4	3
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57	39	38	37	35	34	33	32	5	4
58	40	39	38	36	35	34	33	5	4
59	40	39	38	36	35	34	33	5	4
60	41	40	39	37	36	35	34	5	4
″	41	40	39	37	36	35	34	5	4

Proportional Parts

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	53405	35	46595	56107	39	43893	02701	5	97299	60
1	440	35	560	146	39	854	706	5	294	59
2	475	34	525	185	39	815	711	4	289	58
3	509	35	491	224	40	776	715	5	285	57
4	544	34	456	264	39	736	720	4	280	56
5	578	35	422	303	39	697	724	5	276	55
6	613	34	387	342	39	658	729	5	271	54
7	647	35	353	381	39	619	734	4	266	53
8	682	34	318	420	39	580	738	5	262	52
9	716	35	284	459	39	541	743	5	257	51
10	751	34	249	498	39	502	748	4	252	50
11	785	34	215	537	39	463	752	5	248	49
12	819	35	181	576	39	424	757	5	243	48
13	854	34	146	615	39	385	762	4	238	47
14	888	34	112	654	39	346	766	5	234	46
15	922	35	078	693	39	307	771	5	229	45
16	957	34	043	732	39	268	776	4	224	44
17	991	34	009	771	39	229	780	5	220	43
18	54025	34	45975	810	39	190	785	5	215	42
19	059	34	941	849	38	151	790	4	210	41
20	093	34	907	887	39	113	794	5	206	40
21	127	34	873	926	39	074	799	5	201	39
22	161	34	839	965	39	035	804	4	196	38
23	195	34	805	57004	38	42996	808	5	192	37
24	229	34	771	042	39	958	813	5	187	36
25	263	34	737	081	39	919	818	4	182	35
26	297	34	703	120	38	880	822	5	178	34
27	331	34	669	158	39	842	827	5	173	33
28	365	34	635	197	38	803	832	5	168	32
29	399	34	601	235	39	765	837	4	163	31
30	54433	33	45567	57274	38	42726	02841	5	97159	30
31	466	34	534	312	39	688	846	5	154	29
32	500	34	500	351	38	649	851	4	149	28
33	534	33	466	389	39	611	855	5	145	27
34	567	34	433	428	38	572	860	5	140	26
35	601	34	399	466	38	534	865	5	135	25
36	635	33	365	504	39	496	870	4	130	24
37	668	34	332	543	38	457	874	5	126	23
38	702	33	298	581	38	419	879	5	121	22
39	735	34	265	619	39	381	884	5	116	21
40	769	33	231	658	38	342	889	4	111	20
41	802	34	198	696	38	304	893	5	107	19
42	836	33	164	734	38	266	898	5	102	18
43	869	34	131	772	38	228	903	5	097	17
44	903	33	097	810	39	190	908	5	092	16
45	936	33	064	849	38	151	913	4	087	15
46	969	34	031	887	38	113	917	5	083	14
47	55003	33	44997	925	38	075	922	5	078	13
48	036	33	964	963	38	037	927	5	073	12
49	069	33	931	58001	38	41999	932	5	068	11
50	102	34	898	039	38	961	937	4	063	10
51	136	33	864	077	38	923	941	5	059	9
52	169	33	831	115	38	885	946	5	054	8
53	202	33	798	153	38	847	951	5	049	7
54	235	33	765	191	38	809	956	5	044	6
55	268	33	732	229	38	771	961	4	039	5
56	301	33	699	267	37	733	965	5	035	4
57	334	33	666	304	38	696	970	5	030	3
58	367	33	633	342	38	658	975	5	025	2
59	400	33	600	380	38	620	980	5	020	1
60	55433		44567	58418		41582	02985		97015	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts 40	39	38	37	35	34	33	5	4
0	0	0	0	0	0	0	0	0	0
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3	2	2	2	2	2	2	2	0	0
4	3	3	3	2	2	2	2	0	0
5	3	3	3	3	3	3	3	0	0
6	4	4	4	4	4	3	3	0	0
7	5	5	4	4	4	4	4	1	0
8	5	5	5	5	5	5	4	1	1
9	6	6	6	6	5	5	5	1	1
10	7	6	6	6	6	6	6	1	1
11	7	7	7	7	6	6	6	1	1
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20	13	13	13	12	12	11	11	2	1
21	14	14	13	13	12	12	12	2	1
22	15	14	14	14	13	12	12	2	1
23	15	15	15	14	13	13	13	2	2
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57	38	37	36	35	33	32	31	5	4
58	39	38	37	36	34	33	32	5	4
59	39	38	37	36	34	33	32	5	4
60	40	39	38	37	35	34	33	5	4
″	40 Proportional Parts	39	38	37	35	34	33	5	4

110° 69°

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	55433	33	44567	58418	37	41582	02985	5	97015	60
1	466	33	534	455	38	545	990	5	010	59
2	499	33	501	493	38	507	995	4	005	58
3	532	32	468	531	38	469	999	5	001	57
4	564	33	436	569	37	431	03004	5	96996	56
5	597	33	403	606	38	394	009	5	991	55
6	630	33	370	644	37	356	014	5	986	54
7	663	32	337	681	38	319	019	5	981	53
8	695	33	305	719	38	281	024	5	976	52
9	728	33	272	757	37	243	029	5	971	51
10	761	32	239	794	38	206	034	4	966	50
11	793	33	207	832	37	168	038	5	962	49
12	826	32	174	869	38	131	043	5	957	48
13	858	33	142	907	37	093	048	5	952	47
14	891	32	109	944	37	056	053	5	947	46
15	923	33	077	981	38	019	058	5	942	45
16	956	32	044	59019	37	40981	063	5	937	44
17	988	33	012	056	38	944	068	5	932	43
18	56021	32	43979	094	37	906	073	5	927	42
19	053	32	947	131	37	869	078	5	922	41
20	085	33	915	168	37	832	083	5	917	40
21	118	32	882	205	38	795	088	5	912	39
22	150	32	850	243	37	757	093	4	907	38
23	182	33	818	280	37	720	097	5	903	37
24	215	32	785	317	37	683	102	5	898	36
25	247	32	753	354	37	646	107	5	893	35
26	279	32	721	391	38	609	112	5	888	34
27	311	32	689	429	37	571	117	5	883	33
28	343	32	657	466	37	534	122	5	878	32
29	375	33	625	503	37	497	127	5	873	31
30	56408	32	43592	59540	37	40460	03132	5	96868	30
31	440	32	560	577	37	423	137	5	863	29
32	472	32	528	614	37	386	142	5	858	28
33	504	32	496	651	37	349	147	5	853	27
34	536	32	464	688	37	312	152	5	848	26
35	568	31	432	725	37	275	157	5	843	25
36	599	32	401	762	37	238	162	5	838	24
37	631	32	369	799	36	201	167	5	833	23
38	663	32	337	835	37	165	172	5	828	22
39	695	32	305	872	37	128	177	5	823	21
40	727	32	273	909	37	091	182	5	818	20
41	759	31	241	946	37	054	187	5	813	19
42	790	32	210	983	36	017	192	5	808	18
43	822	32	178	60019	37	39981	197	5	803	17
44	854	32	146	056	37	944	202	5	798	16
45	886	31	114	093	37	907	207	5	793	15
46	917	32	083	130	36	870	212	5	788	14
47	949	31	051	166	37	834	217	5	783	13
48	980	32	020	203	37	797	222	6	778	12
49	57012	32	42988	240	36	760	228	5	772	11
50	044	31	956	276	37	724	233	5	767	10
51	075	32	925	313	36	687	238	5	762	9
52	107	31	893	349	37	651	243	5	757	8
53	138	31	862	386	36	614	248	5	752	7
54	169	32	831	422	37	578	253	5	747	6
55	201	31	799	459	36	541	258	5	742	5
56	232	32	768	495	37	505	263	5	737	4
57	264	31	736	532	36	468	268	5	732	3
58	295	31	705	568	37	432	273	5	727	2
59	326	32	674	605	36	395	278	5	722	1
60	57358		42642	60641		39359	03283		96717	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	38	37	36	33	32	31	6	5	4
0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	0	0	0
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3	2	2	2	2	2	2	0	0	0
4	3	2	2	2	2	2	0	0	0
5	3	3	3	3	3	3	0	0	0
6	4	4	4	3	3	3	1	0	0
7	4	4	4	4	4	4	1	1	0
8	5	5	5	4	4	4	1	1	1
9	6	6	5	5	5	5	1	1	1
10	6	6	6	6	5	5	1	1	1
11	7	7	7	6	6	6	1	1	1
12	8	7	7	7	6	6	1	1	1
13	8	8	8	7	7	7	1	1	1
14	9	9	8	8	7	7	1	1	1
15	10	9	9	8	8	8	2	1	1
16	10	10	10	9	9	8	2	1	1
17	11	10	10	9	9	9	2	1	1
18	11	11	11	10	10	9	2	2	1
19	12	12	11	10	10	10	2	2	1
20	13	12	12	11	11	10	2	2	1
21	13	13	13	12	11	11	2	2	1
22	14	14	13	12	12	11	2	2	1
23	15	14	14	13	12	12	2	2	2
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57	36	35	34	31	30	29	6	5	4
58	37	36	35	32	31	30	6	5	4
59	37	36	35	32	31	30	6	5	4
60	38	37	36	33	32	31	6	5	4
″	38	37	36	33	32	31	6	5	4

Proportional Parts

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	57358	31	42642	60641	36	39359	03283	6	96717	60
1	389	31	611	677	37	323	289	5	711	59
2	420	31	580	714	36	286	294	5	706	58
3	451	31	549	750	36	250	299	5	701	57
4	482	32	518	786	37	214	304	5	696	56
5	514	31	486	823	36	177	309	5	691	55
6	545	31	455	859	36	141	314	5	686	54
7	576	31	424	895	36	105	319	5	681	53
8	607	31	393	931	36	069	324	6	676	52
9	638	31	362	967	37	033	330	5	670	51
10	669	31	331	61004	36	38996	335	5	665	50
11	700	31	300	040	36	960	340	5	660	49
12	731	31	269	076	36	924	345	5	655	48
13	762	31	238	112	36	888	350	5	650	47
14	793	31	207	148	36	852	355	5	645	46
15	824	31	176	184	36	816	360	6	640	45
16	855	30	145	220	36	780	366	5	634	44
17	885	31	115	256	36	744	371	5	629	43
18	916	31	084	292	36	708	376	5	624	42
19	947	31	053	328	36	672	381	5	619	41
20	978	30	022	364	36	636	386	6	614	40
21	58008	31	41992	400	36	600	392	5	608	39
22	039	31	961	436	36	564	397	5	603	38
23	070	31	930	472	36	528	402	5	598	37
24	101	30	899	508	36	492	407	5	593	36
25	131	31	869	544	35	456	412	6	588	35
26	162	30	838	579	36	421	418	5	582	34
27	192	31	808	615	36	385	423	5	577	33
28	223	30	777	651	36	349	428	5	572	32
29	253	31	747	687	35	313	433	5	567	31
30	58284	30	41716	61722	36	38278	03438	6	96562	30
31	314	31	686	758	36	242	444	5	556	29
32	345	30	655	794	36	206	449	5	551	28
33	375	31	625	830	35	170	454	5	546	27
34	406	30	594	865	36	135	459	6	541	26
35	436	31	564	901	35	099	465	5	535	25
36	467	30	533	936	36	064	470	5	530	24
37	497	30	503	972	36	028	475	5	525	23
38	527	30	473	62008	35	37992	480	6	520	22
39	557	31	443	043	36	957	486	5	514	21
40	588	30	412	079	35	921	491	5	509	20
41	618	30	382	114	36	886	496	6	504	19
42	648	30	352	150	35	850	502	5	498	18
43	678	31	322	185	36	815	507	5	493	17
44	709	30	291	221	35	779	512	5	488	16
45	739	30	261	256	36	744	517	6	483	15
46	769	30	231	292	35	708	523	5	477	14
47	799	30	201	327	35	673	528	5	472	13
48	829	30	171	362	36	638	533	6	467	12
49	859	30	141	398	35	602	539	5	461	11
50	889	30	111	433	35	567	544	5	456	10
51	919	30	081	468	36	532	549	6	451	9
52	949	30	051	504	35	496	555	5	445	8
53	979	30	021	539	35	461	560	5	440	7
54	59009	30	40991	574	35	426	565	6	435	6
55	039	30	961	609	36	391	571	5	429	5
56	069	29	931	645	35	355	576	5	424	4
57	098	30	902	680	35	320	581	6	419	3
58	128	30	872	715	35	285	587	5	413	2
59	158	30	842	750	35	250	592	5	408	1
60	59188		40812	62785		37215	03597		96403	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts 37	36	35	32	31	30	29	6	5
0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	0	0	0	0
2	1	1	1	1	1	1	1	0	0
3	2	2	2	2	2	2	1	0	0
4	2	2	2	2	2	2	2	0	0
5	3	3	3	3	3	2	2	0	0
6	4	4	4	3	3	3	3	1	0
7	4	4	4	4	4	4	3	1	1
8	5	5	5	4	4	4	4	1	1
9	6	5	5	5	5	4	4	1	1
10	6	6	6	5	5	5	5	1	1
11	7	7	6	6	6	6	5	1	1
12	7	7	7	6	6	6	6	1	1
13	8	8	8	7	7	6	6	1	1
14	9	8	8	7	7	7	7	1	1
15	9	9	9	8	8	8	7	2	1
16	10	10	9	9	8	8	8	2	1
17	10	10	10	9	9	8	8	2	1
18	11	11	10	10	9	9	9	2	2
19	12	11	11	10	10	10	9	2	2
20	12	12	12	11	10	10	10	2	2
21	13	13	12	11	11	10	10	2	2
22	14	13	13	12	11	11	11	2	2
23	14	14	13	12	12	12	11	2	2
24	15	14	14	13	12	12	12	2	2
25	15	15	15	13	13	12	12	2	2
26	16	16	15	14	13	13	13	3	2
27	17	16	16	14	14	14	13	3	2
28	17	17	16	15	14	14	14	3	2
29	18	17	17	15	15	14	14	3	2
30	18	18	18	16	16	15	14	3	2
31	19	19	18	17	16	16	15	3	3
32	20	19	19	17	17	16	15	3	3
33	20	20	19	18	17	16	16	3	3
34	21	20	20	18	18	17	16	3	3
35	22	21	20	19	18	18	17	4	3
36	22	22	21	19	19	18	17	4	3
37	23	22	22	20	19	18	18	4	3
38	23	23	22	20	20	19	18	4	3
39	24	23	23	21	20	20	19	4	3
40	25	24	23	21	21	20	19	4	3
41	25	25	24	22	21	20	20	4	3
42	26	25	24	22	22	21	20	4	4
43	27	26	25	23	22	22	21	4	4
44	27	26	26	23	23	22	21	4	4
45	28	27	26	24	23	22	22	4	4
46	28	28	27	25	24	23	22	5	4
47	29	28	27	25	24	24	23	5	4
48	30	29	28	26	25	24	23	5	4
49	30	29	29	26	25	24	24	5	4
50	31	30	29	27	26	25	24	5	4
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52	32	31	30	28	27	26	25	5	4
53	33	32	31	28	27	26	26	5	4
54	33	32	32	29	28	27	26	5	4
55	34	33	32	29	28	28	27	6	5
56	35	34	33	30	29	28	27	6	5
57	35	34	33	30	29	28	28	6	5
58	36	35	34	31	30	29	28	6	5
59	36	35	34	31	30	30	29	6	5
60	37	36	35	32	31	30	29	6	5
″	37 Proportional Parts	36	35	32	31	30	29	6	5

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	59188	30	40812	62785	35	37215	03597	6	96403	60
1	218	29	782	820	35	180	603	5	397	59
2	247	30	753	855	35	145	608	5	392	58
3	277	30	723	890	36	110	613	6	387	57
4	307	29	693	926	35	074	619	5	381	56
5	336	30	664	961	35	039	624	6	376	55
6	366	30	634	996	35	004	630	5	370	54
7	396	29	604	63031	35	36969	635	5	365	53
8	425	30	575	066	35	934	640	6	360	52
9	455	29	545	101	34	899	646	5	354	51
10	484	30	516	135	35	865	651	6	349	50
11	514	29	486	170	35	830	657	5	343	49
12	543	30	457	205	35	795	662	5	338	48
13	573	29	427	240	35	760	667	6	333	47
14	602	30	398	275	35	725	673	5	327	46
15	632	29	368	310	35	690	678	6	322	45
16	661	29	339	345	34	655	684	5	316	44
17	690	30	310	379	35	621	689	6	311	43
18	720	29	280	414	35	586	695	5	305	42
19	749	29	251	449	35	551	700	6	300	41
20	778	30	222	484	35	516	706	5	294	40
21	808	29	192	519	34	481	711	5	289	39
22	837	29	163	553	35	447	716	6	284	38
23	866	29	134	588	35	412	722	5	278	37
24	895	29	105	623	34	377	727	6	273	36
25	924	30	076	657	35	343	733	5	267	35
26	954	29	046	692	34	308	738	6	262	34
27	983	29	017	726	35	274	744	5	256	33
28	60012	29	39988	761	35	239	749	6	251	32
29	041	29	959	796	34	204	755	5	245	31
30	60070	29	39930	63830	35	36170	03760	6	96240	30
31	099	29	901	865	34	135	766	5	234	29
32	128	29	872	899	35	101	771	6	229	28
33	157	29	843	934	34	066	777	5	223	27
34	186	29	814	968	35	032	782	6	218	26
35	215	29	785	64003	34	35997	788	5	212	25
36	244	29	756	037	35	963	793	6	207	24
37	273	29	727	072	34	928	799	5	201	23
38	302	29	698	106	34	894	804	6	196	22
39	331	28	669	140	35	860	810	5	190	21
40	359	29	641	175	34	825	815	6	185	20
41	388	29	612	209	34	791	821	5	179	19
42	417	29	583	243	35	757	826	6	174	18
43	446	28	554	278	34	722	832	6	168	17
44	474	29	526	312	34	688	838	5	162	16
45	503	29	497	346	35	654	843	6	157	15
46	532	29	468	381	34	619	849	5	151	14
47	561	28	439	415	34	585	854	6	146	13
48	589	29	411	449	34	551	860	5	140	12
49	618	28	382	483	34	517	865	6	135	11
50	646	29	354	517	35	483	871	6	129	10
51	675	29	325	552	34	448	877	5	123	9
52	704	28	296	586	34	414	882	6	118	8
53	732	29	268	620	34	380	888	5	112	7
54	761	28	239	654	34	346	893	6	107	6
55	789	29	211	688	34	312	899	6	101	5
56	818	28	182	722	34	278	905	5	095	4
57	846	29	154	756	34	244	910	6	090	3
58	875	28	125	790	34	210	916	5	084	2
59	903	28	097	824	34	176	921	6	079	1
60	60931		39069	64858		35142	03927		96073	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

Proportional Parts

″	36	35	34	30	29	28	6	5
0	0	0	0	0	0	0	0	0
1	1	1	1	0	0	0	0	0
2	1	1	1	1	1	1	0	0
3	2	2	2	2	1	1	0	0
4	2	2	2	2	2	2	0	0
5	3	3	3	2	2	2	0	0
6	4	4	3	3	3	3	1	0
7	4	4	4	4	3	3	1	1
8	5	5	5	4	4	4	1	1
9	5	5	5	4	4	4	1	1
10	6	6	6	5	5	5	1	1
11	7	6	6	6	5	5	1	1
12	7	7	7	6	6	6	1	1
13	8	8	7	6	6	6	1	1
14	8	8	8	7	7	7	1	1
15	9	9	8	8	7	7	2	1
16	10	9	9	8	8	7	2	1
17	10	10	10	8	8	8	2	1
18	11	10	10	9	9	8	2	2
19	11	11	11	10	9	9	2	2
20	12	12	11	10	10	9	2	2
21	13	12	12	10	10	10	2	2
22	13	13	12	11	11	10	2	2
23	14	13	13	12	11	11	2	2
24	14	14	14	12	12	11	2	2
25	15	15	14	12	12	12	2	2
26	16	15	15	13	13	12	3	2
27	16	16	15	14	13	13	3	2
28	17	16	16	14	14	13	3	2
29	17	17	16	14	14	14	3	2
30	18	18	17	15	14	14	3	2
31	19	18	18	16	15	14	3	3
32	19	19	18	16	15	15	3	3
33	20	19	19	16	16	15	3	3
34	20	20	19	17	16	16	3	3
35	21	20	20	18	17	16	4	3
36	22	21	20	18	17	17	4	3
37	22	22	21	18	18	17	4	3
38	23	22	22	19	18	18	4	3
39	23	23	22	20	19	18	4	3
40	24	23	23	20	19	19	4	3
41	25	24	23	20	20	19	4	3
42	25	24	24	21	20	20	4	4
43	26	25	24	22	21	20	4	4
44	26	26	25	22	21	21	4	4
45	27	26	26	22	22	21	4	4
46	28	27	26	23	22	21	5	4
47	28	27	27	24	23	22	5	4
48	29	28	27	24	23	22	5	4
49	29	29	28	24	24	23	5	4
50	30	29	28	25	24	23	5	4
51	31	30	29	26	25	24	5	4
52	31	30	29	26	25	24	5	4
53	32	31	30	26	26	25	5	4
54	32	32	31	27	26	25	5	4
55	33	32	31	28	27	26	6	5
56	34	33	32	28	27	26	6	5
57	34	33	32	28	28	27	6	5
58	35	34	33	29	28	27	6	5
59	35	34	33	30	29	28	6	5
60	36	35	34	30	29	28	6	5
″	36	35	34	30	29	28	6	5

Proportional Parts

113° 66°

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	60931	29	39069	64858	34	35142	03927	6	96073	60
1	960	28	040	892	34	108	933	5	067	59
2	988	28	012	926	34	074	938	6	062	58
3	61016	29	38984	960	34	040	944	6	056	57
4	045	28	955	994	34	006	950	5	050	56
5	073	28	927	65028	34	34972	955	6	045	55
6	101	28	899	062	34	938	961	5	039	54
7	129	29	871	096	34	904	966	6	034	53
8	158	28	842	130	34	870	972	6	028	52
9	186	28	814	164	33	836	978	5	022	51
10	214	28	786	197	34	803	983	6	017	50
11	242	28	758	231	34	769	989	6	011	49
12	270	28	730	265	34	735	995	5	005	48
13	298	28	702	299	34	701	04000	6	000	47
14	326	28	674	333	33	667	006	6	95994	46
15	354	28	646	366	34	634	012	6	988	45
16	382	29	618	400	34	600	018	5	982	44
17	411	27	589	434	33	566	023	6	977	43
18	438	28	562	467	34	533	029	6	971	42
19	466	28	534	501	34	499	035	5	965	41
20	494	28	506	535	33	465	040	6	960	40
21	522	28	478	568	34	432	046	6	954	39
22	550	28	450	602	34	398	052	6	948	38
23	578	28	422	636	33	364	058	5	942	37
24	606	28	394	669	34	331	063	6	937	36
25	634	28	366	703	33	297	069	6	931	35
26	662	27	338	736	34	264	075	5	925	34
27	689	28	311	770	33	230	080	6	920	33
28	717	28	283	803	34	197	086	6	914	32
29	745	28	255	837	33	163	092	6	908	31
30	61773	27	38227	65870	34	34130	04098	5	95902	30
31	800	28	200	904	33	096	103	6	897	29
32	828	28	172	937	34	063	109	6	891	28
33	856	27	144	971	33	029	115	6	885	27
34	883	28	117	66004	34	33996	121	6	879	26
35	911	28	089	038	33	962	127	5	873	25
36	939	27	061	071	33	929	132	6	868	24
37	966	28	034	104	34	896	138	6	862	23
38	994	27	006	138	33	862	144	6	856	22
39	62021	28	37979	171	33	829	150	6	850	21
40	049	27	951	204	34	796	156	5	844	20
41	076	28	924	238	33	762	161	6	839	19
42	104	27	896	271	33	729	167	6	833	18
43	131	28	869	304	33	696	173	6	827	17
44	159	27	841	337	34	663	179	6	821	16
45	186	28	814	371	33	629	185	5	815	15
46	214	27	786	404	33	596	190	6	810	14
47	241	27	759	437	33	563	196	6	804	13
48	268	28	732	470	33	530	202	6	798	12
49	296	27	704	503	34	497	208	6	792	11
50	323	27	677	537	33	463	214	6	786	10
51	350	27	650	570	33	430	220	5	780	9
52	377	28	623	603	33	397	225	6	775	8
53	405	27	595	636	33	364	231	6	769	7
54	432	27	568	669	33	331	237	6	763	6
55	459	27	541	702	33	298	243	6	757	5
56	486	27	514	735	33	265	249	6	751	4
57	513	28	487	768	33	232	255	6	745	3
58	541	27	459	801	33	199	261	6	739	2
59	568	27	432	834	33	166	267	5	733	1
60	62595		37405	66867		33133	04272		95728	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts 34	33	29	28	27	6	5
0	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0
2	1	1	1	1	1	0	0
3	2	2	1	1	1	0	0
4	2	2	2	2	2	0	0
5	3	3	2	2	2	0	0
6	3	3	3	3	3	1	0
7	4	4	3	3	3	1	1
8	5	4	4	4	4	1	1
9	5	5	4	4	4	1	1
10	6	6	5	5	4	1	1
11	6	6	5	5	5	1	1
12	7	7	6	6	5	1	1
13	7	7	6	6	6	1	1
14	8	8	7	7	6	1	1
15	8	8	7	7	7	2	1
16	9	9	8	7	7	2	1
17	10	9	8	8	8	2	1
18	10	10	9	8	8	2	2
19	11	10	9	9	9	2	2
20	11	11	10	9	9	2	2
21	12	12	10	10	9	2	2
22	12	12	11	10	10	2	2
23	13	13	11	11	10	2	2
24	14	13	12	11	11	2	2
25	14	14	12	12	11	2	2
26	15	14	13	12	12	3	2
27	15	15	13	13	12	3	2
28	16	15	14	13	13	3	2
29	16	16	14	14	13	3	2
30	17	16	14	14	14	3	2
31	18	17	15	14	14	3	3
32	18	18	15	15	14	3	3
33	19	18	16	15	15	3	3
34	19	19	16	16	15	3	3
35	20	19	17	16	16	4	3
36	20	20	17	17	16	4	3
37	21	20	18	17	17	4	3
38	22	21	18	18	17	4	3
39	22	21	19	18	18	4	3
40	23	22	19	19	18	4	3
41	23	23	20	19	18	4	3
42	24	23	20	20	19	4	4
43	24	24	21	20	19	4	4
44	25	24	21	21	20	4	4
45	26	25	22	21	20	4	4
46	26	25	22	21	21	5	4
47	27	26	23	22	21	5	4
48	27	26	23	22	22	5	4
49	28	27	24	23	22	5	4
50	28	28	24	23	22	5	4
51	29	28	25	24	23	5	4
52	29	29	25	24	23	5	4
53	30	29	26	25	24	5	4
54	31	30	26	25	24	5	4
55	31	30	27	26	25	6	5
56	32	31	27	26	25	6	5
57	32	31	28	27	26	6	5
58	33	32	28	27	26	6	5
59	33	32	29	28	27	6	5
60	34	33	29	28	27	6	5
″	34 Proportional Parts	33	29	28	27	6	5

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	62595	27	37405	66867	33	33133	04272	6	95728	60
1	622	27	378	900	33	100	278	6	722	59
2	649	27	351	933	33	067	284	6	716	58
3	676	27	324	966	33	034	290	6	710	57
4	703	27	297	999	33	001	296	6	704	56
5	730	27	270	67032	33	32968	302	6	698	55
6	757	27	243	065	33	935	308	6	692	54
7	784	27	216	098	33	902	314	6	686	53
8	811	27	189	131	32	869	320	6	680	52
9	838	27	162	163	33	837	326	6	674	51
10	865	27	135	196	33	804	332	5	668	50
11	892	26	108	229	33	771	337	6	663	49
12	918	27	082	262	33	738	343	6	657	48
13	945	27	055	295	32	705	349	6	651	47
14	972	27	028	327	33	673	355	6	645	46
15	999	27	001	360	33	640	361	6	639	45
16	63026	26	36974	393	33	607	367	6	633	44
17	052	27	948	426	32	574	373	6	627	43
18	079	27	921	458	33	542	379	6	621	42
19	106	27	894	491	33	509	385	6	615	41
20	133	26	867	524	32	476	391	6	609	40
21	159	27	841	556	33	444	397	6	603	39
22	186	27	814	589	33	411	403	6	597	38
23	213	26	787	622	32	378	409	6	591	37
24	239	27	761	654	33	346	415	6	585	36
25	266	26	734	687	32	313	421	6	579	35
26	292	27	708	719	33	281	427	6	573	34
27	319	26	681	752	33	248	433	6	567	33
28	345	27	655	785	32	215	439	6	561	32
29	372	26	628	817	33	183	445	6	555	31
30	63398	27	36602	67850	32	32150	04451	6	95549	30
31	425	26	575	882	33	118	457	6	543	29
32	451	27	549	915	32	085	463	6	537	28
33	478	26	522	947	33	053	469	6	531	27
34	504	27	496	980	32	020	475	6	525	26
35	531	26	469	68012	32	31988	481	6	519	25
36	557	26	443	044	33	956	487	6	513	24
37	583	27	417	077	32	923	493	7	507	23
38	610	26	390	109	33	891	500	6	500	22
39	636	26	364	142	32	858	506	6	494	21
40	662	27	338	174	32	826	512	6	488	20
41	689	26	311	206	33	794	518	6	482	19
42	715	26	285	239	32	761	524	6	476	18
43	741	26	259	271	32	729	530	6	470	17
44	767	27	233	303	33	697	536	6	464	16
45	794	26	206	336	32	664	542	6	458	15
46	820	26	180	368	32	632	548	6	452	14
47	846	26	154	400	32	600	554	6	446	13
48	872	26	128	432	33	568	560	6	440	12
49	898	26	102	465	32	535	566	7	434	11
50	924	26	076	497	32	503	573	6	427	10
51	950	26	050	529	32	471	579	6	421	9
52	976	26	024	561	32	439	585	6	415	8
53	64002	26	35998	593	33	407	591	6	409	7
54	028	26	972	626	32	374	597	6	403	6
55	054	26	946	658	32	342	603	6	397	5
56	080	26	920	690	32	310	609	7	391	4
57	106	26	894	722	32	278	616	6	384	3
58	132	26	868	754	32	246	622	6	378	2
59	158	26	842	786	32	214	628	6	372	1
60	64184		35816	68818		31182	04634		95366	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

Proportional Parts

″	33	32	27	26	7	6	5
0	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0
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3	2	2	1	1	0	0	0
4	2	2	2	2	0	0	0
5	3	3	2	2	1	0	0
6	3	3	3	3	1	1	0
7	4	4	3	3	1	1	1
8	4	4	4	3	1	1	1
9	5	5	4	4	1	1	1
10	6	5	4	4	1	1	1
11	6	6	5	5	1	1	1
12	7	6	5	5	1	1	1
13	7	7	6	6	2	1	1
14	8	7	6	6	2	1	1
15	8	8	7	6	2	2	1
16	9	9	7	7	2	2	1
17	9	9	8	7	2	2	1
18	10	10	8	8	2	2	2
19	10	10	9	8	2	2	2
20	11	11	9	9	2	2	2
21	12	11	9	9	2	2	2
22	12	12	10	10	3	2	2
23	13	12	10	10	3	2	2
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26	14	14	12	11	3	3	2
27	15	14	12	12	3	3	2
28	15	15	13	12	3	3	2
29	16	15	13	13	3	3	2
30	16	16	14	13	4	3	2
31	17	17	14	13	4	3	3
32	18	17	14	14	4	3	3
33	18	18	15	14	4	3	3
34	19	18	15	15	4	3	3
35	19	19	16	15	4	4	3
36	20	19	16	16	4	4	3
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44	24	23	20	19	5	4	4
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54	30	29	24	23	6	5	4
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57	31	30	26	25	7	6	5
58	32	31	26	25	7	6	5
59	32	31	27	26	7	6	5
60	33	32	27	26	7	6	5
″	33	32	27	26	7	6	5

Proportional Parts

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	64184	26	35816	68818	32	31182	04634	6	95366	60
1	210	26	790	850	32	150	640	6	360	59
2	236	26	764	882	32	118	646	6	354	58
3	262	26	738	914	32	086	652	7	348	57
4	288	25	712	946	32	054	659	6	341	56
5	313	26	687	978	32	022	665	6	335	55
6	339	26	661	69010	32	30990	671	6	329	54
7	365	26	635	042	32	958	677	6	323	53
8	391	26	609	074	32	926	683	7	317	52
9	417	25	583	106	32	894	690	6	310	51
10	442	26	558	138	32	862	696	6	304	50
11	468	26	532	170	32	830	702	6	298	49
12	494	25	506	202	32	798	708	6	292	48
13	519	26	481	234	32	766	714	7	286	47
14	545	26	455	266	32	734	721	6	279	46
15	571	25	429	298	31	702	727	6	273	45
16	596	26	404	329	32	671	733	6	267	44
17	622	25	378	361	32	639	739	7	261	43
18	647	26	353	393	32	607	746	6	254	42
19	673	25	327	425	32	575	752	6	248	41
20	698	26	302	457	31	543	758	6	242	40
21	724	25	276	488	32	512	764	7	236	39
22	749	26	251	520	32	480	771	6	229	38
23	775	25	225	552	32	448	777	6	223	37
24	800	26	200	584	31	416	783	6	217	36
25	826	25	174	615	32	385	789	7	211	35
26	851	26	149	647	32	353	796	6	204	34
27	877	25	123	679	31	321	802	6	198	33
28	902	25	098	710	32	290	808	7	192	32
29	927	26	073	742	32	258	815	6	185	31
30	64953	25	35047	69774	31	30226	04821	6	95179	30
31	978	25	022	805	32	195	827	6	173	29
32	65003	26	34997	837	31	163	833	7	167	28
33	029	25	971	868	32	132	840	6	160	27
34	054	25	946	900	32	100	846	6	154	26
35	079	25	921	932	31	068	852	7	148	25
36	104	26	896	963	32	037	859	6	141	24
37	130	25	870	995	31	005	865	6	135	23
38	155	25	845	70026	32	29974	871	7	129	22
39	180	25	820	058	31	942	878	6	122	21
40	205	25	795	089	32	911	884	6	116	20
41	230	25	770	121	31	879	890	7	110	19
42	255	26	745	152	32	848	897	6	103	18
43	281	25	719	184	31	816	903	7	097	17
44	306	25	694	215	32	785	910	6	090	16
45	331	25	669	247	31	753	916	6	084	15
46	356	25	644	278	31	722	922	7	078	14
47	381	25	619	309	32	691	929	6	071	13
48	406	25	594	341	31	659	935	6	065	12
49	431	25	569	372	32	628	941	7	059	11
50	456	25	544	404	31	596	948	6	052	10
51	481	25	519	435	31	565	954	7	046	9
52	506	25	494	466	32	534	961	6	039	8
53	531	25	469	498	31	502	967	6	033	7
54	556	24	444	529	31	471	973	7	027	6
55	580	25	420	560	32	440	980	6	020	5
56	605	25	395	592	31	408	986	7	014	4
57	630	25	370	623	31	377	993	6	007	3
58	655	25	345	654	31	346	999	6	001	2
59	680	25	320	685	32	315	05005	7	94995	1
60	65705		34295	70717		29283	05012		94988	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts 32	31	26	25	24	7	6
0	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0
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4	2	2	2	2	2	0	0
5	3	3	2	2	2	1	0
6	3	3	3	2	2	1	1
7	4	4	3	3	3	1	1
8	4	4	3	3	3	1	1
9	5	5	4	4	4	1	1
10	5	5	4	4	4	1	1
11	6	6	5	5	4	1	1
12	6	6	5	5	5	1	1
13	7	7	6	5	5	2	1
14	7	7	6	6	6	2	1
15	8	8	6	6	6	2	2
16	9	8	7	7	6	2	2
17	9	9	7	7	7	2	2
18	10	9	8	8	7	2	2
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22	12	11	10	9	9	3	2
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25	13	13	11	10	10	3	2
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44	23	23	19	18	18	5	4
45	24	23	20	19	18	5	4
46	25	24	20	19	18	5	5
47	25	24	20	20	19	5	5
48	26	25	21	20	19	6	5
49	26	25	21	20	20	6	5
50	27	26	22	21	20	6	5
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56	30	29	24	23	22	7	6
57	30	29	25	24	23	7	6
58	31	30	25	24	23	7	6
59	31	30	26	25	24	7	6
60	32	31	26	25	24	7	6
″	32 Proportional Parts	31	26	25	24	7	6

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	65705	24	34295	70717	31	29283	05012	6	94988	60
1	729	25	271	748	31	252	018	7	982	59
2	754	25	246	779	31	221	025	6	975	58
3	779	25	221	810	31	190	031	7	969	57
4	804	24	196	841	32	159	038	6	962	56
5	828	25	172	873	31	127	044	7	956	55
6	853	25	147	904	31	096	051	6	949	54
7	878	24	122	935	31	065	057	7	943	53
8	902	25	098	966	31	034	064	6	936	52
9	927	25	073	997	31	003	070	7	930	51
10	952	24	048	71028	31	28972	077	6	923	50
11	976	25	024	059	31	941	083	6	917	49
12	66001	24	33999	090	31	910	089	7	911	48
13	025	25	975	121	32	879	096	6	904	47
14	050	25	950	153	31	847	102	7	898	46
15	075	24	925	184	31	816	109	6	891	45
16	099	25	901	215	31	785	115	7	885	44
17	124	24	876	246	31	754	122	7	878	43
18	148	25	852	277	31	723	129	6	871	42
19	173	24	827	308	31	692	135	7	865	41
20	197	24	803	339	31	661	142	6	858	40
21	221	25	779	370	31	630	148	7	852	39
22	246	24	754	401	30	599	155	6	845	38
23	270	25	730	431	31	569	161	7	839	37
24	295	24	705	462	31	538	168	6	832	36
25	319	24	681	493	31	507	174	7	826	35
26	343	25	657	524	31	476	181	6	819	34
27	368	24	632	555	31	445	187	7	813	33
28	392	24	608	586	31	414	194	7	806	32
29	416	25	584	617	31	383	201	6	799	31
30	66441	24	33559	71648	31	28352	05207	7	94793	30
31	465	24	535	679	30	321	214	6	786	29
32	489	24	511	709	31	291	220	7	780	28
33	513	24	487	740	31	260	227	6	773	27
34	537	25	463	771	31	229	233	7	767	26
35	562	24	438	802	31	198	240	7	760	25
36	586	24	414	833	30	167	247	6	753	24
37	610	24	390	863	31	137	253	7	747	23
38	634	24	366	894	31	106	260	6	740	22
39	658	24	342	925	30	075	266	7	734	21
40	682	24	318	955	31	045	273	7	727	20
41	706	25	294	986	31	014	280	6	720	19
42	731	24	269	72017	31	27983	286	7	714	18
43	755	24	245	048	30	952	293	7	707	17
44	779	24	221	078	31	922	300	6	700	16
45	803	24	197	109	31	891	306	7	694	15
46	827	24	173	140	30	860	313	7	687	14
47	851	24	149	170	31	830	320	6	680	13
48	875	24	125	201	30	799	326	7	674	12
49	899	23	101	231	31	769	333	7	667	11
50	922	24	078	262	31	738	340	6	660	10
51	946	24	054	293	30	707	346	7	654	9
52	970	24	030	323	31	677	353	7	647	8
53	994	24	006	354	30	646	360	6	640	7
54	67018	24	32982	384	31	616	366	7	634	6
55	042	24	958	415	30	585	373	7	627	5
56	066	24	934	445	31	555	380	6	620	4
57	090	23	910	476	30	524	386	7	614	3
58	113	24	887	506	31	494	393	7	607	2
59	137	24	863	537	30	463	400	7	600	1
60	67161		32839	72567		27433	05407		94593	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	32	31	30	25	24	23	7	6
0	0	0	0	0	0	0	0	0
1	1	1	0	0	0	0	0	0
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3	2	2	2	1	1	1	0	0
4	2	2	2	2	2	2	0	0
5	3	3	2	2	2	2	1	0
6	3	3	3	2	2	2	1	1
7	4	4	4	3	3	3	1	1
8	4	4	4	3	3	3	1	1
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10	5	5	5	4	4	4	1	1
11	6	6	6	5	4	4	1	1
12	6	6	6	5	5	5	1	1
13	7	7	6	5	5	5	2	1
14	7	7	7	6	6	5	2	1
15	8	8	8	6	6	6	2	2
16	9	8	8	7	6	6	2	2
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44	23	23	22	18	18	17	5	4
45	24	23	22	19	18	17	5	4
46	25	24	23	19	18	18	5	5
47	25	24	24	20	19	18	5	5
48	26	25	24	20	19	18	6	5
49	26	25	24	20	20	19	6	5
50	27	26	25	21	20	19	6	5
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56	30	29	28	23	22	21	7	6
57	30	29	28	24	23	22	7	6
58	31	30	29	24	23	22	7	6
59	31	30	30	25	24	23	7	6
60	32	31	30	25	24	23	7	6
″	32	31	30	25	24	23	7	6

Proportional Parts

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	67161	24	32839	72567	31	27433	05407	6	94593	60
1	185	23	815	598	30	402	413	7	587	59
2	208	24	792	628	31	372	420	7	580	58
3	232	24	768	659	30	341	427	6	573	57
4	256	24	744	689	31	311	433	7	567	56
5	280	23	720	720	30	280	440	7	560	55
6	303	24	697	750	30	250	447	7	553	54
7	327	23	673	780	31	220	454	6	546	53
8	350	24	650	811	30	189	460	7	540	52
9	374	24	626	841	31	159	467	7	533	51
10	398	23	602	872	30	128	474	7	526	50
11	421	24	579	902	30	098	481	6	519	49
12	445	23	555	932	31	068	487	7	513	48
13	468	24	532	963	30	037	494	7	506	47
14	492	23	508	993	30	007	501	7	499	46
15	515	24	485	73023	31	26977	508	7	492	45
16	539	23	461	054	30	946	515	6	485	44
17	562	24	438	084	30	916	521	7	479	43
18	586	23	414	114	30	886	528	7	472	42
19	609	24	391	144	31	856	535	7	465	41
20	633	23	367	175	30	825	542	7	458	40
21	656	24	344	205	30	795	549	6	451	39
22	680	23	320	235	30	765	555	7	445	38
23	703	23	297	265	30	735	562	7	438	37
24	726	24	274	295	31	705	569	7	431	36
25	750	23	250	326	30	674	576	7	424	35
26	773	23	227	356	30	644	583	7	417	34
27	796	24	204	386	30	614	590	6	410	33
28	820	23	180	416	30	584	596	7	404	32
29	843	23	157	446	30	554	603	7	397	31
30	67866	24	32134	73476	31	26524	05610	7	94390	30
31	890	23	110	507	30	493	617	7	383	29
32	913	23	087	537	30	463	624	7	376	28
33	936	23	064	567	30	433	631	7	369	27
34	959	23	041	597	30	403	638	7	362	26
35	982	24	018	627	30	373	645	6	355	25
36	68006	23	31994	657	30	343	651	7	349	24
37	029	23	971	687	30	313	658	7	342	23
38	052	23	948	717	30	283	665	7	335	22
39	075	23	925	747	30	253	672	7	328	21
40	098	23	902	777	30	223	679	7	321	20
41	121	23	879	807	30	193	686	7	314	19
42	144	23	856	837	30	163	693	7	307	18
43	167	23	833	867	30	133	700	7	300	17
44	190	23	810	897	30	103	707	7	293	16
45	213	24	787	927	30	073	714	7	286	15
46	237	23	763	957	30	043	721	6	279	14
47	260	23	740	987	30	013	727	7	273	13
48	283	22	717	74017	30	25983	734	7	266	12
49	305	23	695	047	30	953	741	7	259	11
50	328	23	672	077	30	923	748	7	252	10
51	351	23	649	107	30	893	755	7	245	9
52	374	23	626	137	29	863	762	7	238	8
53	397	23	603	166	30	834	769	7	231	7
54	420	23	580	196	30	804	776	7	224	6
55	443	23	557	226	30	774	783	7	217	5
56	466	23	534	256	30	744	790	7	210	4
57	489	23	511	286	30	714	797	7	203	3
58	512	22	488	316	29	684	804	7	196	2
59	534	23	466	345	30	655	811	7	189	1
60	68557		31443	74375		25625	05818		94182	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts 31	30	29	24	23	22	7	6
0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	0	0	0
2	1	1	1	1	1	1	0	0
3	2	2	1	1	1	1	0	0
4	2	2	2	2	2	1	0	0
5	3	2	2	2	2	2	1	0
6	3	3	3	2	2	2	1	1
7	4	4	3	3	3	3	1	1
8	4	4	4	3	3	3	1	1
9	5	4	4	4	3	3	1	1
10	5	5	5	4	4	4	1	1
11	6	6	5	4	4	4	1	1
12	6	6	6	5	5	4	1	1
13	7	6	6	5	5	5	2	1
14	7	7	7	6	5	5	2	1
15	8	8	7	6	6	6	2	2
16	8	8	8	6	6	6	2	2
17	9	8	8	7	7	6	2	2
18	9	9	9	7	7	7	2	2
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22	11	11	11	9	8	8	3	2
23	12	12	11	9	9	8	3	2
24	12	12	12	10	9	9	3	2
25	13	12	12	10	10	9	3	2
26	13	13	13	10	10	10	3	3
27	14	14	13	11	10	10	3	3
28	14	14	14	11	11	10	3	3
29	15	14	14	12	11	11	3	3
30	16	15	14	12	12	11	4	3
31	16	16	15	12	12	11	4	3
32	17	16	15	13	12	12	4	3
33	17	16	16	13	13	12	4	3
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35	18	18	17	14	13	13	4	4
36	19	18	17	14	14	13	4	4
37	19	18	18	15	14	14	4	4
38	20	19	18	15	15	14	4	4
39	20	20	19	16	15	14	5	4
40	21	20	19	16	15	15	5	4
41	21	20	20	16	16	15	5	4
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44	23	22	21	18	17	16	5	4
45	23	22	22	18	17	16	5	4
46	24	23	22	18	18	17	5	5
47	24	24	23	19	18	17	5	5
48	25	24	23	19	18	18	6	5
49	25	24	24	20	19	18	6	5
50	26	25	24	20	19	18	6	5
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57	29	28	28	23	22	21	7	6
58	30	29	28	23	22	21	7	6
59	30	30	29	24	23	22	7	6
60	31	30	29	24	23	22	7	6
″	31 Proportional Parts	30	29	24	23	22	7	6

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	68557	23	31443	74375	30	25625	05818	7	94182	60
1	580	23	420	405	30	595	825	7	175	59
2	603	22	397	435	30	565	832	7	168	58
3	625	23	375	465	29	535	839	7	161	57
4	648	23	352	494	30	506	846	7	154	56
5	671	23	329	524	30	476	853	7	147	55
6	694	22	306	554	29	446	860	7	140	54
7	716	23	284	583	30	417	867	7	133	53
8	739	23	261	613	30	387	874	7	126	52
9	762	22	238	643	30	357	881	7	119	51
10	784	23	216	673	29	327	888	7	112	50
11	807	22	193	702	30	298	895	7	105	49
12	829	23	171	732	30	268	902	8	098	48
13	852	23	148	762	29	238	910	7	090	47
14	875	22	125	791	30	209	917	7	083	46
15	897	23	103	821	30	179	924	7	076	45
16	920	22	080	851	29	149	931	7	069	44
17	942	23	058	880	30	120	938	7	062	43
18	965	22	035	910	29	090	945	7	055	42
19	987	23	013	939	30	061	952	7	048	41
20	69010	22	30990	969	29	031	959	7	041	40
21	032	23	968	998	30	002	966	7	034	39
22	055	22	945	75028	30	24972	973	7	027	38
23	077	23	923	058	29	942	980	8	020	37
24	100	22	900	087	30	913	988	7	012	36
25	122	22	878	117	29	883	995	7	005	35
26	144	23	856	146	30	854	06002	7	93998	34
27	167	22	833	176	29	824	009	7	991	33
28	189	23	811	205	30	795	016	7	984	32
29	212	22	788	235	29	765	023	7	977	31
30	69234	22	30766	75264	30	24736	06030	7	93970	30
31	256	23	744	294	29	706	037	8	963	29
32	279	22	721	323	30	677	045	7	955	28
33	301	22	699	353	29	647	052	7	948	27
34	323	22	677	382	29	618	059	7	941	26
35	345	23	655	411	30	589	066	7	934	25
36	368	22	632	441	29	559	073	7	927	24
37	390	22	610	470	30	530	080	8	920	23
38	412	22	588	500	29	500	088	7	912	22
39	434	22	566	529	29	471	095	7	905	21
40	456	23	544	558	30	442	102	7	898	20
41	479	22	521	588	29	412	109	7	891	19
42	501	22	499	617	30	383	116	8	884	18
43	523	22	477	647	29	353	124	7	876	17
44	545	22	455	676	29	324	131	7	869	16
45	567	22	433	705	30	295	138	7	862	15
46	589	22	411	735	29	265	145	8	855	14
47	611	22	389	764	29	236	153	7	847	13
48	633	22	367	793	29	207	160	7	840	12
49	655	22	345	822	30	178	167	7	833	11
50	677	22	323	852	29	148	174	7	826	10
51	699	22	301	881	29	119	181	8	819	9
52	721	22	279	910	29	090	189	7	811	8
53	743	22	257	939	30	061	196	7	804	7
54	765	22	235	969	29	031	203	8	797	6
55	787	22	213	998	29	002	211	7	789	5
56	809	22	191	76027	29	23973	218	7	782	4
57	831	22	169	056	30	944	225	7	775	3
58	853	22	147	086	29	914	232	8	768	2
59	875	22	125	115	29	885	240	7	760	1
60	69897		30103	76144		23856	06247		93753	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

Proportional Parts

″	30	29	23	22	8	7
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	1	1	1	1	0	0
3	2	1	1	1	0	0
4	2	2	2	1	1	0
5	2	2	2	2	1	1
6	3	3	2	2	1	1
7	4	3	3	3	1	1
8	4	4	3	3	1	1
9	4	4	3	3	1	1
10	5	5	4	4	1	1
11	6	5	4	4	1	1
12	6	6	5	4	2	1
13	6	6	5	5	2	2
14	7	7	5	5	2	2
15	8	7	6	6	2	2
16	8	8	6	6	2	2
17	8	8	7	6	2	2
18	9	9	7	7	2	2
19	10	9	7	7	3	2
20	10	10	8	7	3	2
21	10	10	8	8	3	2
22	11	11	8	8	3	3
23	12	11	9	8	3	3
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45	22	22	17	16	6	5
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47	24	23	18	17	6	5
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49	24	24	19	18	7	6
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53	26	26	20	19	7	6
54	27	26	21	20	7	6
55	28	27	21	20	7	6
56	28	27	21	21	7	7
57	28	28	22	21	8	7
58	29	28	22	21	8	7
59	30	29	23	22	8	7
60	30	29	23	22	8	7
″	30	29	23	22	8	7

Proportional Parts

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	69897	22	30103	76144	29	23856	06247	7	93753	60
1	919	22	081	173	29	827	254	8	746	59
2	941	22	059	202	29	798	262	7	738	58
3	963	21	037	231	30	769	269	7	731	57
4	984	22	016	261	29	739	276	7	724	56
5	70006	22	29994	290	29	710	283	8	717	55
6	028	22	972	319	29	681	291	7	709	54
7	050	22	950	348	29	652	298	7	702	53
8	072	21	928	377	29	623	305	8	695	52
9	093	22	907	406	29	594	313	7	687	51
10	115	22	885	435	29	565	320	7	680	50
11	137	22	863	464	29	536	327	8	673	49
12	159	21	841	493	29	507	335	7	665	48
13	180	22	820	522	29	478	342	8	658	47
14	202	22	798	551	29	449	350	7	650	46
15	224	21	776	580	29	420	357	7	643	45
16	245	22	755	609	30	391	364	8	636	44
17	267	21	733	639	29	361	372	7	628	43
18	288	22	712	668	29	332	379	7	621	42
19	310	22	690	697	28	303	386	8	614	41
20	332	21	668	725	29	275	394	7	606	40
21	353	22	647	754	29	246	401	8	599	39
22	375	21	625	783	29	217	409	7	591	38
23	396	22	604	812	29	188	416	7	584	37
24	418	21	582	841	29	159	423	8	577	36
25	439	22	561	870	29	130	431	7	569	35
26	461	21	539	899	29	101	438	8	562	34
27	482	22	518	928	29	072	446	7	554	33
28	504	21	496	957	29	043	453	8	547	32
29	525	22	475	986	29	014	461	7	539	31
30	70547	21	29453	77015	29	22985	06468	7	93532	30
31	568	22	432	044	29	956	475	8	525	29
32	590	21	410	073	28	927	483	7	517	28
33	611	22	389	101	29	899	490	8	510	27
34	633	21	367	130	29	870	498	7	502	26
35	654	21	346	159	29	841	505	8	495	25
36	675	22	325	188	29	812	513	7	487	24
37	697	21	303	217	29	783	520	8	480	23
38	718	21	282	246	28	754	528	7	472	22
39	739	22	261	274	29	726	535	8	465	21
40	761	21	239	303	29	697	543	7	457	20
41	782	21	218	332	29	668	550	8	450	19
42	803	21	197	361	29	639	558	7	442	18
43	824	22	176	390	28	610	565	8	435	17
44	846	21	154	418	29	582	573	7	427	16
45	867	21	133	447	29	553	580	8	420	15
46	888	21	112	476	29	524	588	7	412	14
47	909	22	091	505	28	495	595	8	405	13
48	931	21	069	533	29	467	603	7	397	12
49	952	21	048	562	29	438	610	8	390	11
50	973	21	027	591	28	409	618	7	382	10
51	994	21	006	619	29	381	625	8	375	9
52	71015	21	28985	648	29	352	633	7	367	8
53	036	22	964	677	29	323	640	8	360	7
54	058	21	942	706	28	294	648	8	352	6
55	079	21	921	734	29	266	656	7	344	5
56	100	21	900	763	28	237	663	8	337	4
57	121	21	879	791	29	209	671	7	329	3
58	142	21	858	820	29	180	678	8	322	2
59	163	21	837	849	28	151	686	7	314	1
60	71184		28816	77877		22123	06693		93307	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

Proportional Parts

″	30	29	28	22	21	8	7
0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0
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4	2	2	2	1	1	1	0
5	2	2	2	2	2	1	1
6	3	3	3	2	2	1	1
7	4	3	3	3	2	1	1
8	4	4	4	3	3	1	1
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17	8	8	8	6	6	2	2
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34	17	16	16	12	12	5	4
35	18	17	16	13	12	5	4
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37	18	18	17	14	13	5	4
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45	22	22	21	16	16	6	5
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47	24	23	22	17	16	6	5
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54	27	26	25	20	19	7	6
55	28	27	26	20	19	7	6
56	28	27	26	21	20	7	7
57	28	28	27	21	20	8	7
58	29	28	27	21	20	8	7
59	30	29	28	22	21	8	7
60	30	29	28	22	21	8	7
″	30	29	28	22	21	8	7

Proportional Parts

′	*l* sin 9.	d 1′	*l* csc 10.	*l* tan 9.	d 1′	*l* cot 10.	*l* sec 10.	d 1′	*l* cos 9.	′
0	71184	21	28816	77877	29	22123	06693	8	93307	60
1	205	21	795	906	29	094	701	8	299	59
2	226	21	774	935	28	065	709	7	291	58
3	247	21	753	963	29	037	716	8	284	57
4	268	21	732	992	28	008	724	7	276	56
5	289	21	711	78020	29	21980	731	8	269	55
6	310	21	690	049	28	951	739	8	261	54
7	331	21	669	077	29	923	747	7	253	53
8	352	21	648	106	29	894	754	8	246	52
9	373	20	627	135	28	865	762	8	238	51
10	393	21	607	163	29	837	770	7	230	50
11	414	21	586	192	28	808	777	8	223	49
12	435	21	565	220	29	780	785	8	215	48
13	456	21	544	249	28	751	793	7	207	47
14	477	21	523	277	29	723	800	8	200	46
15	498	21	502	306	28	694	808	8	192	45
16	519	20	481	334	29	666	816	7	184	44
17	539	21	461	363	28	637	823	8	177	43
18	560	21	440	391	28	609	831	8	169	42
19	581	21	419	419	29	581	839	7	161	41
20	602	20	398	448	28	552	846	8	154	40
21	622	21	378	476	29	524	854	8	146	39
22	643	21	357	505	28	495	862	7	138	38
23	664	21	336	533	29	467	869	8	131	37
24	685	20	315	562	28	438	877	8	123	36
25	705	21	295	590	28	410	885	7	115	35
26	726	21	274	618	29	382	892	8	108	34
27	747	20	253	647	28	353	900	8	100	33
28	767	21	233	675	29	325	908	8	092	32
29	788	21	212	704	28	296	916	7	084	31
30	71809	20	28191	78732	28	21268	06923	8	93077	30
31	829	21	171	760	29	240	931	8	069	29
32	850	20	150	789	28	211	939	8	061	28
33	870	21	130	817	28	183	947	7	053	27
34	891	20	109	845	29	155	954	8	046	26
35	911	21	089	874	28	126	962	8	038	25
36	932	20	068	902	28	098	970	8	030	24
37	952	21	048	930	29	070	978	8	022	23
38	973	21	027	959	28	041	986	7	014	22
39	994	20	006	987	28	013	993	8	007	21
40	72014	20	27986	79015	28	20985	07001	8	92999	20
41	034	21	966	043	29	957	009	8	991	19
42	055	20	945	072	28	928	017	7	983	18
43	075	21	925	100	28	900	024	8	976	17
44	096	20	904	128	28	872	032	8	968	16
45	116	21	884	156	29	844	040	8	960	15
46	137	20	863	185	28	815	048	8	952	14
47	157	20	843	213	28	787	056	8	944	13
48	177	21	823	241	28	759	064	7	936	12
49	198	20	802	269	28	731	071	8	929	11
50	218	20	782	297	29	703	079	8	921	10
51	238	21	762	326	28	674	087	8	913	9
52	259	20	741	354	28	646	095	8	905	8
53	279	20	721	382	28	618	103	8	897	7
54	299	21	701	410	28	590	111	8	889	6
55	320	20	680	438	28	562	119	7	881	5
56	340	20	660	466	29	534	126	8	874	4
57	360	21	640	495	28	505	134	8	866	3
58	381	20	619	523	28	477	142	8	858	2
59	401	20	599	551	28	449	150	8	850	1
60	72421		27579	79579		20421	07158		92842	0
′	9. *l* cos	d 1′	10. *l* sec	9. *l* cot	d 1′	10. *l* tan	10. *l* csc	d 1′	9. *l* sin	′

Proportional Parts

″	29	28	21	20	8	7
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	1	1	1	1	0	0
3	1	1	1	1	0	0
4	2	2	1	1	1	0
5	2	2	2	2	1	1
6	3	3	2	2	1	1
7	3	3	2	2	1	1
8	4	4	3	3	1	1
9	4	4	3	3	1	1
10	5	5	4	3	1	1
11	5	5	4	4	1	1
12	6	6	4	4	2	1
13	6	6	5	4	2	2
14	7	7	5	5	2	2
15	7	7	5	5	2	2
16	8	7	6	5	2	2
17	8	8	6	6	2	2
18	9	8	6	6	2	2
19	9	9	7	6	3	2
20	10	9	7	7	3	2
21	10	10	7	7	3	2
22	11	10	8	7	3	3
23	11	11	8	8	3	3
24	12	11	8	8	3	3
25	12	12	9	8	3	3
26	13	12	9	9	3	3
27	13	13	9	9	4	3
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33	16	15	12	11	4	4
34	16	16	12	11	5	4
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36	17	17	13	12	5	4
37	18	17	13	12	5	4
38	18	18	13	13	5	4
39	19	18	14	13	5	5
40	19	19	14	13	5	5
41	20	19	14	14	5	5
42	20	20	15	14	6	5
43	21	20	15	14	6	5
44	21	21	15	15	6	5
45	22	21	16	15	6	5
46	22	21	16	15	6	5
47	23	22	16	16	6	5
48	23	22	17	16	6	6
49	24	23	17	16	7	6
50	24	23	18	17	7	6
51	25	24	18	17	7	6
52	25	24	18	17	7	6
53	26	25	19	18	7	6
54	26	25	19	18	7	6
55	27	26	19	18	7	6
56	27	26	20	19	7	7
57	28	27	20	19	8	7
58	28	27	20	19	8	7
59	29	28	21	20	8	7
60	29	28	21	20	8	7
″	29	28	21	20	8	7

Proportional Parts

121° 58°

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	72421	20	27579	79579	28	20421	07158	8	92842	60
1	441	20	559	607	28	393	166	8	834	59
2	461	21	539	635	28	365	174	8	826	58
3	482	20	518	663	28	337	182	8	818	57
4	502	20	498	691	28	309	190	7	810	56
5	522	20	478	719	28	281	197	8	803	55
6	542	20	458	747	29	253	205	8	795	54
7	562	20	438	776	28	224	213	8	787	53
8	582	20	418	804	28	196	221	8	779	52
9	602	20	398	832	28	168	229	8	771	51
10	622	21	378	860	28	140	237	8	763	50
11	643	20	357	888	28	112	245	8	755	49
12	663	20	337	916	28	084	253	8	747	48
13	683	20	317	944	28	056	261	8	739	47
14	703	20	297	972	28	028	269	8	731	46
15	723	20	277	80000	28	000	277	8	723	45
16	743	20	257	028	28	19972	285	8	715	44
17	763	20	237	056	28	944	293	8	707	43
18	783	20	217	084	28	916	301	8	699	42
19	803	20	197	112	28	888	309	8	691	41
20	823	20	177	140	28	860	317	8	683	40
21	843	20	157	168	27	832	325	8	675	39
22	863	20	137	195	28	805	333	8	667	38
23	883	19	117	223	28	777	341	8	659	37
24	902	20	098	251	28	749	349	8	651	36
25	922	20	078	279	28	721	357	8	643	35
26	942	20	058	307	28	693	365	8	635	34
27	962	20	038	335	28	665	373	8	627	33
28	982	20	018	363	28	637	381	8	619	32
29	73002	20	26998	391	28	609	389	8	611	31
30	73022	19	26978	80419	28	19581	07397	8	92603	30
31	041	20	959	447	27	553	405	8	595	29
32	061	20	939	474	28	526	413	8	587	28
33	081	20	919	502	28	498	421	8	579	27
34	101	20	899	530	28	470	429	8	571	26
35	121	19	879	558	28	442	437	8	563	25
36	140	20	860	586	28	414	445	9	555	24
37	160	20	840	614	28	386	454	8	546	23
38	180	20	820	642	27	358	462	8	538	22
39	200	19	800	669	28	331	470	8	530	21
40	219	20	781	697	28	303	478	8	522	20
41	239	20	761	725	28	275	486	8	514	19
42	259	19	741	753	28	247	494	8	506	18
43	278	20	722	781	27	219	502	8	498	17
44	298	20	702	808	28	192	510	8	490	16
45	318	19	682	836	28	164	518	9	482	15
46	337	20	663	864	28	136	527	8	473	14
47	357	20	643	892	27	108	535	8	465	13
48	377	19	623	919	28	081	543	8	457	12
49	396	20	604	947	28	053	551	8	449	11
50	416	19	584	975	28	025	559	8	441	10
51	435	20	565	81003	27	18997	567	8	433	9
52	455	19	545	030	28	970	575	9	425	8
53	474	20	526	058	28	942	584	8	416	7
54	494	19	506	086	27	914	592	8	408	6
55	513	20	487	113	28	887	600	8	400	5
56	533	19	467	141	28	859	608	8	392	4
57	552	20	448	169	27	831	616	8	384	3
58	572	19	428	196	28	804	624	9	376	2
59	591	20	409	224	28	776	633	8	367	1
60	73611		26389	81252		18748	07641		92359	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

Proportional Parts

″	29	28	27	21	20	19	9	8	7
0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0
2	1	1	1	1	1	1	0	0	0
3	1	1	1	1	1	1	0	0	0
4	2	2	2	1	1	1	1	1	0
5	2	2	2	2	2	2	1	1	1
6	3	3	3	2	2	2	1	1	1
7	3	3	3	2	2	2	1	1	1
8	4	4	4	3	3	3	1	1	1
9	4	4	4	3	3	3	1	1	1
10	5	5	4	4	3	3	2	1	1
11	5	5	5	4	4	3	2	1	1
12	6	6	5	4	4	4	2	2	1
13	6	6	6	5	4	4	2	2	2
14	7	7	6	5	5	4	2	2	2
15	7	7	7	5	5	5	2	2	2
16	8	7	7	6	5	5	2	2	2
17	8	8	8	6	6	5	3	2	2
18	9	8	8	6	6	6	3	2	2
19	9	9	9	7	6	6	3	3	2
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21	10	10	9	7	7	7	3	3	2
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23	11	11	10	8	8	7	3	3	3
24	12	11	11	8	8	8	4	3	3
25	12	12	11	9	8	8	4	3	3
26	13	12	12	9	9	8	4	3	3
27	13	13	12	9	9	9	4	4	3
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33	16	15	15	12	11	10	5	4	4
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45	22	21	20	16	15	14	7	6	5
46	22	21	21	16	15	15	7	6	5
47	23	22	21	16	16	15	7	6	5
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57	28	27	26	20	19	18	9	8	7
58	28	27	26	20	19	18	9	8	7
59	29	28	27	21	20	19	9	8	7
60	29	28	27	21	20	19	9	8	7
″	29	28	27	21	20	19	9	8	7

Proportional Parts

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	73611	19	26389	81252	27	18748	07641	8	92359	60
1	630	20	370	279	28	721	649	8	351	59
2	650	19	350	307	28	693	657	8	343	58
3	669	20	331	335	27	665	665	9	335	57
4	689	19	311	362	28	638	674	8	326	56
5	708	19	292	390	28	610	682	8	318	55
6	727	20	273	418	27	582	690	8	310	54
7	747	19	253	445	28	555	698	9	302	53
8	766	19	234	473	27	527	707	8	293	52
9	785	20	215	500	28	500	715	8	285	51
10	805	19	195	528	28	472	723	8	277	50
11	824	19	176	556	27	444	731	9	269	49
12	843	20	157	583	28	417	740	8	260	48
13	863	19	137	611	27	389	748	8	252	47
14	882	19	118	638	28	362	756	9	244	46
15	901	20	099	666	27	334	765	8	235	45
16	921	19	079	693	28	307	773	8	227	44
17	940	19	060	721	27	279	781	8	219	43
18	959	19	041	748	28	252	789	9	211	42
19	978	19	022	776	27	224	798	8	202	41
20	997	20	003	803	28	197	806	8	194	40
21	74017	19	25983	831	27	169	814	9	186	39
22	036	19	964	858	28	142	823	8	177	38
23	055	19	945	886	27	114	831	8	169	37
24	074	19	926	913	28	087	839	9	161	36
25	093	20	907	941	27	059	848	8	152	35
26	113	19	887	968	28	032	856	8	144	34
27	132	19	868	996	27	004	864	9	136	33
28	151	19	849	82023	28	17977	873	8	127	32
29	170	19	830	051	27	949	881	8	119	31
30	74189	19	25811	82078	28	17922	07889	9	92111	30
31	208	19	792	106	27	894	898	8	102	29
32	227	19	773	133	28	867	906	8	094	28
33	246	19	754	161	27	839	914	9	086	27
34	265	19	735	188	27	812	923	8	077	26
35	284	19	716	215	28	785	931	9	069	25
36	303	19	697	243	27	757	940	8	060	24
37	322	19	678	270	28	730	948	8	052	23
38	341	19	659	298	27	702	956	9	044	22
39	360	19	640	325	27	675	965	8	035	21
40	379	19	621	352	28	648	973	9	027	20
41	398	19	602	380	27	620	982	8	018	19
42	417	19	583	407	28	593	990	8	010	18
43	436	19	564	435	27	565	998	9	002	17
44	455	19	545	462	27	538	08007	8	91993	16
45	474	19	526	489	28	511	015	9	985	15
46	493	19	507	517	27	483	024	8	976	14
47	512	19	488	544	27	456	032	9	968	13
48	531	18	469	571	28	429	041	8	959	12
49	549	19	451	599	27	401	049	9	951	11
50	568	19	432	626	27	374	058	8	942	10
51	587	19	413	653	28	347	066	9	934	9
52	606	19	394	681	27	319	075	8	925	8
53	625	19	375	708	27	292	083	9	917	7
54	644	18	356	735	27	265	092	8	908	6
55	662	19	338	762	28	238	100	9	900	5
56	681	19	319	790	27	210	109	8	891	4
57	700	19	300	817	27	183	117	9	883	3
58	719	18	281	844	27	156	126	8	874	2
59	737	19	263	871	28	129	134	9	866	1
60	74756		25244	82899		17101	08143		91857	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

Proportional Parts

″	28	27	20	19	18	9	8
0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0
2	1	1	1	1	1	0	0
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4	2	2	1	1	1	1	1
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6	3	3	2	2	2	1	1
7	3	3	2	2	2	1	1
8	4	4	3	3	2	1	1
9	4	4	3	3	3	1	1
10	5	4	3	3	3	2	1
11	5	5	4	3	3	2	1
12	6	5	4	4	4	2	2
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17	8	8	6	5	5	3	2
18	8	8	6	6	5	3	2
19	9	9	6	6	6	3	3
20	9	9	7	6	6	3	3
21	10	9	7	7	6	3	3
22	10	10	7	7	7	3	3
23	11	10	8	7	7	3	3
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25	12	11	8	8	8	4	3
26	12	12	9	8	8	4	3
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34	16	15	11	11	10	5	5
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45	21	20	15	14	14	7	6
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47	22	21	16	15	14	7	6
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55	26	25	18	17	16	8	7
56	26	25	19	18	17	8	7
57	27	26	19	18	17	9	8
58	27	26	19	18	17	9	8
59	28	27	20	19	18	9	8
60	28	27	20	19	18	9	8
″	28	27	20	19	18	9	8

Proportional Parts

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	74756	19	25244	82899	27	17101	08143	8	91857	60
1	775	19	225	926	27	074	151	9	849	59
2	794	18	206	953	27	047	160	8	840	58
3	812	19	188	980	28	020	168	9	832	57
4	831	19	169	83008	27	16992	177	8	823	56
5	850	18	150	035	27	965	185	9	815	55
6	868	19	132	062	27	938	194	8	806	54
7	887	19	113	089	28	911	202	9	798	53
8	906	18	094	117	27	883	211	8	789	52
9	924	19	076	144	27	856	219	9	781	51
10	943	18	057	171	27	829	228	9	772	50
11	961	19	039	198	27	802	237	8	763	49
12	980	19	020	225	27	775	245	9	755	48
13	999	18	001	252	28	748	254	8	746	47
14	75017	19	24983	280	27	720	262	9	738	46
15	036	18	964	307	27	693	271	9	729	45
16	054	19	946	334	27	666	280	8	720	44
17	073	18	927	361	27	639	288	9	712	43
18	091	19	909	388	27	612	297	8	703	42
19	110	18	890	415	27	585	305	9	695	41
20	128	19	872	442	28	558	314	9	686	40
21	147	18	853	470	27	530	323	8	677	39
22	165	19	835	497	27	503	331	9	669	38
23	184	18	816	524	27	476	340	9	660	37
24	202	19	798	551	27	449	349	8	651	36
25	221	18	779	578	27	422	357	9	643	35
26	239	19	761	605	27	395	366	9	634	34
27	258	18	742	632	27	368	375	8	625	33
28	276	18	724	659	27	341	383	9	617	32
29	294	19	706	686	27	314	392	9	608	31
30	75313	18	24687	83713	27	16287	08401	8	91599	30
31	331	19	669	740	28	260	409	9	591	29
32	350	18	650	768	27	232	418	9	582	28
33	368	18	632	795	27	205	427	8	573	27
34	386	19	614	822	27	178	435	9	565	26
35	405	18	595	849	27	151	444	9	556	25
36	423	18	577	876	27	124	453	9	547	24
37	441	18	559	903	27	097	462	8	538	23
38	459	19	541	930	27	070	470	9	530	22
39	478	18	522	957	27	043	479	9	521	21
40	496	18	504	984	27	016	488	8	512	20
41	514	19	486	84011	27	15989	496	9	504	19
42	533	18	467	038	27	962	505	9	495	18
43	551	18	449	065	27	935	514	9	486	17
44	569	18	431	092	27	908	523	8	477	16
45	587	18	413	119	27	881	531	9	469	15
46	605	19	395	146	27	854	540	9	460	14
47	624	18	376	173	27	827	549	9	451	13
48	642	18	358	200	27	800	558	9	442	12
49	660	18	340	227	27	773	567	8	433	11
50	678	18	322	254	26	746	575	9	425	10
51	696	18	304	280	27	720	584	9	416	9
52	714	19	286	307	27	693	593	9	407	8
53	733	18	267	334	27	666	602	9	398	7
54	751	18	249	361	27	639	611	8	389	6
55	769	18	231	388	27	612	619	9	381	5
56	787	18	213	415	27	585	628	9	372	4
57	805	18	195	442	27	558	637	9	363	3
58	823	18	177	469	27	531	646	9	354	2
59	841	18	159	496	27	504	655	9	345	1
60	75859		24141	84523		15477	08664		91336	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

Proportional Parts ″	28	27	26	19	18	9	8
0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0
2	1	1	1	1	1	0	0
3	1	1	1	1	1	0	0
4	2	2	2	1	1	1	1
5	2	2	2	2	2	1	1
6	3	3	3	2	2	1	1
7	3	3	3	2	2	1	1
8	4	4	3	3	2	1	1
9	4	4	4	3	3	1	1
10	5	4	4	3	3	2	1
11	5	5	5	3	3	2	1
12	6	5	5	4	4	2	2
13	6	6	6	4	4	2	2
14	7	6	6	4	4	2	2
15	7	7	6	5	4	2	2
16	7	7	7	5	5	2	2
17	8	8	7	5	5	3	2
18	8	8	8	6	5	3	2
19	9	9	8	6	6	3	3
20	9	9	9	6	6	3	3
21	10	9	9	7	6	3	3
22	10	10	10	7	7	3	3
23	11	10	10	7	7	3	3
24	11	11	10	8	7	4	3
25	12	11	11	8	8	4	3
26	12	12	11	8	8	4	3
27	13	12	12	9	8	4	4
28	13	13	12	9	8	4	4
29	14	13	13	9	9	4	4
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31	14	14	13	10	9	5	4
32	15	14	14	10	10	5	4
33	15	15	14	10	10	5	4
34	16	15	15	11	10	5	5
35	16	16	15	11	10	5	5
36	17	16	16	11	11	5	5
37	17	17	16	12	11	6	5
38	18	17	16	12	11	6	5
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41	19	18	18	13	12	6	5
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43	20	19	19	14	13	6	6
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46	21	21	20	15	14	7	6
47	22	21	20	15	14	7	6
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55	26	25	24	17	16	8	7
56	26	25	24	18	17	8	7
57	27	26	25	18	17	9	8
58	27	26	25	18	17	9	8
59	28	27	26	19	18	9	8
60	28	27	26	19	18	9	8
″ Proportional Parts	28	27	26	19	18	9	8

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	75859	18	24141	84523	27	15477	08664	8	91336	60
1	877	18	123	550	26	450	672	9	328	59
2	895	18	105	576	27	424	681	9	319	58
3	913	18	087	603	27	397	690	9	310	57
4	931	18	069	630	27	370	699	9	301	56
5	949	18	051	657	27	343	708	9	292	55
6	967	18	033	684	27	316	717	9	283	54
7	985	18	015	711	27	289	726	8	274	53
8	76003	18	23997	738	26	262	734	9	266	52
9	021	18	979	764	27	236	743	9	257	51
10	039	18	961	791	27	209	752	9	248	50
11	057	18	943	818	27	182	761	9	239	49
12	075	18	925	845	27	155	770	9	230	48
13	093	18	907	872	27	128	779	9	221	47
14	111	18	889	899	26	101	788	9	212	46
15	129	17	871	925	27	075	797	9	203	45
16	146	18	854	952	27	048	806	9	194	44
17	164	18	836	979	27	021	815	9	185	43
18	182	18	818	85006	27	14994	824	9	176	42
19	200	18	800	033	26	967	833	9	167	41
20	218	18	782	059	27	941	842	9	158	40
21	236	17	764	086	27	914	851	8	149	39
22	253	18	747	113	27	887	859	9	141	38
23	271	18	729	140	26	860	868	9	132	37
24	289	18	711	166	27	834	877	9	123	36
25	307	17	693	193	27	807	886	9	114	35
26	324	18	676	220	27	780	895	9	105	34
27	342	18	658	247	26	753	904	9	096	33
28	360	18	640	273	27	727	913	9	087	32
29	378	17	622	300	27	700	922	9	078	31
30	76395	18	23605	85327	27	14673	08931	9	91069	30
31	413	18	587	354	26	646	940	9	060	29
32	431	17	569	380	27	620	949	9	051	28
33	448	18	552	407	27	593	958	9	042	27
34	466	18	534	434	26	566	967	10	033	26
35	484	17	516	460	27	540	977	9	023	25
36	501	18	499	487	27	513	986	9	014	24
37	519	18	481	514	26	486	995	9	005	23
38	537	17	463	540	27	460	09004	9	90996	22
39	554	18	446	567	27	433	013	9	987	21
40	572	18	428	594	26	406	022	9	978	20
41	590	17	410	620	27	380	031	9	969	19
42	607	18	393	647	27	353	040	9	960	18
43	625	17	375	674	26	326	049	9	951	17
44	642	18	358	700	27	300	058	9	942	16
45	660	17	340	727	27	273	067	9	933	15
46	677	18	323	754	26	246	076	9	924	14
47	695	17	305	780	27	220	085	9	915	13
48	712	18	288	807	27	193	094	10	906	12
49	730	17	270	834	26	166	104	9	896	11
50	747	18	253	860	27	140	113	9	887	10
51	765	17	235	887	26	113	122	9	878	9
52	782	18	218	913	27	087	131	9	869	8
53	800	17	200	940	27	060	140	9	860	7
54	817	18	183	967	26	033	149	9	851	6
55	835	17	165	993	27	007	158	10	842	5
56	852	18	148	86020	26	13980	168	9	832	4
57	870	17	130	046	27	954	177	9	823	3
58	887	17	113	073	27	927	186	9	814	2
59	904	18	096	100	26	900	195	9	805	1
60	76922		23078	86126		13874	09204		90796	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts 27	26	18	17	10	9	8
0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0
2	1	1	1	1	0	0	0
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6	3	3	2	2	1	1	1
7	3	3	2	2	1	1	1
8	4	3	2	2	1	1	1
9	4	4	3	3	2	1	1
10	4	4	3	3	2	2	1
11	5	5	3	3	2	2	1
12	5	5	4	3	2	2	2
13	6	6	4	4	2	2	2
14	6	6	4	4	2	2	2
15	7	6	4	4	2	2	2
16	7	7	5	5	3	2	2
17	8	7	5	5	3	3	2
18	8	8	5	5	3	3	2
19	9	8	6	5	3	3	3
20	9	9	6	6	3	3	3
21	9	9	6	6	4	3	3
22	10	10	7	6	4	3	3
23	10	10	7	7	4	3	3
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26	12	11	8	7	4	4	3
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28	13	12	8	8	5	4	4
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31	14	13	9	9	5	5	4
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38	17	16	11	11	6	6	5
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42	19	18	13	12	7	6	6
43	19	19	13	12	7	6	6
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46	21	20	14	13	8	7	6
47	21	20	14	13	8	7	6
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51	23	22	15	14	8	8	7
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53	24	23	16	15	9	8	7
54	24	23	16	15	9	8	7
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56	25	24	17	16	9	8	7
57	26	25	17	16	10	9	8
58	26	25	17	16	10	9	8
59	27	26	18	17	10	9	8
60	27	26	18	17	10	9	8
″	27 Proportional Parts	26	18	17	10	9	8

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	76922	17	23078	86126	27	13874	09204	9	90796	60
1	939	18	061	153	26	847	213	10	787	59
2	957	17	043	179	27	821	223	9	777	58
3	974	17	026	206	26	794	232	9	768	57
4	991	18	009	232	27	768	241	9	759	56
5	77009	17	22991	259	26	741	250	9	750	55
6	026	17	974	285	27	715	259	10	741	54
7	043	18	957	312	26	688	269	9	731	53
8	061	17	939	338	27	662	278	9	722	52
9	078	17	922	365	27	635	287	9	713	51
10	095	17	905	392	26	608	296	10	704	50
11	112	18	888	418	27	582	306	9	694	49
12	130	17	870	445	26	555	315	9	685	48
13	147	17	853	471	27	529	324	9	676	47
14	164	17	836	498	26	502	333	10	667	46
15	181	18	819	524	27	476	343	9	657	45
16	199	17	801	551	26	449	352	9	648	44
17	216	17	784	577	26	423	361	9	639	43
18	233	17	767	603	27	397	370	10	630	42
19	250	18	750	630	26	370	380	9	620	41
20	268	17	732	656	27	344	389	9	611	40
21	285	17	715	683	26	317	398	10	602	39
22	302	17	698	709	27	291	408	9	592	38
23	319	17	681	736	26	264	417	9	583	37
24	336	17	664	762	27	238	426	9	574	36
25	353	17	647	789	26	211	435	10	565	35
26	370	17	630	815	27	185	445	9	555	34
27	387	18	613	842	26	158	454	9	546	33
28	405	17	595	868	26	132	463	10	537	32
29	422	17	578	894	27	106	473	9	527	31
30	77439	17	22561	86921	26	13079	09482	9	90518	30
31	456	17	544	947	27	053	491	10	509	29
32	473	17	527	974	26	026	501	9	499	28
33	490	17	510	87000	27	000	510	10	490	27
34	507	17	493	027	26	12973	520	9	480	26
35	524	17	476	053	26	947	529	9	471	25
36	541	17	459	079	27	921	538	10	462	24
37	558	17	442	106	26	894	548	9	452	23
38	575	17	425	132	26	868	557	9	443	22
39	592	17	408	158	27	842	566	10	434	21
40	609	17	391	185	26	815	576	9	424	20
41	626	17	374	211	27	789	585	10	415	19
42	643	17	357	238	26	762	595	9	405	18
43	660	17	340	264	26	736	604	10	396	17
44	677	17	323	290	27	710	614	9	386	16
45	694	17	306	317	26	683	623	9	377	15
46	711	17	289	343	26	657	632	10	368	14
47	728	16	272	369	27	631	642	9	358	13
48	744	17	256	396	26	604	651	10	349	12
49	761	17	239	422	26	578	661	9	339	11
50	778	17	222	448	27	552	670	10	330	10
51	795	17	205	475	26	525	680	9	320	9
52	812	17	188	501	26	499	689	10	311	8
53	829	17	171	527	27	473	699	9	301	7
54	846	16	154	554	26	446	708	10	292	6
55	862	17	138	580	26	420	718	9	282	5
56	879	17	121	606	27	394	727	10	273	4
57	896	17	104	633	26	367	737	9	263	3
58	913	17	087	659	26	341	746	10	254	2
59	930	16	070	685	26	315	756	9	244	1
60	77946		22054	87711		12289	09765		90235	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	27	26	18	17	16	10	9
	Proportional Parts						
0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0
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3	1	1	1	1	1	0	0
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5	2	2	2	1	1	1	1
6	3	3	2	2	2	1	1
7	3	3	2	2	2	1	1
8	4	3	2	2	2	1	1
9	4	4	3	3	2	2	1
10	4	4	3	3	3	2	2
11	5	5	3	3	3	2	2
12	5	5	4	3	3	2	2
13	6	6	4	4	3	2	2
14	6	6	4	4	4	2	2
15	7	6	4	4	4	2	2
16	7	7	5	5	4	3	2
17	8	7	5	5	5	3	3
18	8	8	5	5	5	3	3
19	9	8	6	5	5	3	3
20	9	9	6	6	5	3	3
21	9	9	6	6	6	4	3
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30	14	13	9	8	8	5	4
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34	15	15	10	10	9	6	5
35	16	15	10	10	9	6	5
36	16	16	11	10	10	6	5
37	17	16	11	10	10	6	6
38	17	16	11	11	10	6	6
39	18	17	12	11	10	6	6
40	18	17	12	11	11	7	6
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42	19	18	13	12	11	7	6
43	19	19	13	12	11	7	6
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54	24	23	16	15	14	9	8
55	25	24	16	16	15	9	8
56	25	24	17	16	15	9	8
57	26	25	17	16	15	10	9
58	26	25	17	16	15	10	9
59	27	26	18	17	16	10	9
60	27	26	18	17	16	10	9
″	27	26	18	17	16	10	9
	Proportional Parts						

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	77946	17	22054	87711	27	12289	09765	10	90235	60
1	963	17	037	738	26	262	775	9	225	59
2	980	17	020	764	26	236	784	10	216	58
3	997	16	003	790	27	210	794	9	206	57
4	78013	17	21987	817	26	183	803	10	197	56
5	030	17	970	843	26	157	813	9	187	55
6	047	16	953	869	26	131	822	10	178	54
7	063	17	937	895	27	105	832	9	168	53
8	080	17	920	922	26	078	841	10	159	52
9	097	16	903	948	26	052	851	10	149	51
10	113	17	887	974	26	026	861	9	139	50
11	130	17	870	88000	27	000	870	10	130	49
12	147	16	853	027	26	11973	880	9	120	48
13	163	17	837	053	26	947	889	10	111	47
14	180	17	820	079	26	921	899	10	101	46
15	197	16	803	105	26	895	909	9	091	45
16	213	17	787	131	27	869	918	10	082	44
17	230	16	770	158	26	842	928	9	072	43
18	246	17	754	184	26	816	937	10	063	42
19	263	17	737	210	26	790	947	10	053	41
20	280	16	720	236	26	764	957	9	043	40
21	296	17	704	262	27	738	966	10	034	39
22	313	16	687	289	26	711	976	10	024	38
23	329	17	671	315	26	685	986	9	014	37
24	346	16	654	341	26	659	995	10	005	36
25	362	17	638	367	26	633	10005	10	89995	35
26	379	16	621	393	27	607	015	9	985	34
27	395	17	605	420	26	580	024	10	976	33
28	412	16	588	446	26	554	034	10	966	32
29	428	17	572	472	26	528	044	9	956	31
30	78445	16	21555	88498	26	11502	10053	10	89947	30
31	461	17	539	524	26	476	063	10	937	29
32	478	16	522	550	27	450	073	9	927	28
33	494	16	506	577	26	423	082	10	918	27
34	510	17	490	603	26	397	092	10	908	26
35	527	16	473	629	26	371	102	10	898	25
36	543	17	457	655	26	345	112	9	888	24
37	560	16	440	681	26	319	121	10	879	23
38	576	16	424	707	26	293	131	10	869	22
39	592	17	408	733	26	267	141	10	859	21
40	609	16	391	759	27	241	151	9	849	20
41	625	17	375	786	26	214	160	10	840	19
42	642	16	358	812	26	188	170	10	830	18
43	658	16	342	838	26	162	180	10	820	17
44	674	17	326	864	26	136	190	9	810	16
45	691	16	309	890	26	110	199	10	801	15
46	707	16	293	916	26	084	209	10	791	14
47	723	16	277	942	26	058	219	10	781	13
48	739	17	261	968	26	032	229	10	771	12
49	756	16	244	994	26	006	239	9	761	11
50	772	16	228	89020	26	10980	248	10	752	10
51	788	17	212	046	27	954	258	10	742	9
52	805	16	195	073	26	927	268	10	732	8
53	821	16	179	099	26	901	278	10	722	7
54	837	16	163	125	26	875	288	10	712	6
55	853	16	147	151	26	849	298	9	702	5
56	869	17	131	177	26	823	307	10	693	4
57	886	16	114	203	26	797	317	10	683	3
58	902	16	098	229	26	771	327	10	673	2
59	918	16	082	255	26	745	337	10	663	1
60	78934		21066	89281		10719	10347		89653	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

Proportional Parts

″	27	26	17	16	10	9
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	1	1	1	1	0	0
3	1	1	1	1	0	0
4	2	2	1	1	1	1
5	2	2	1	1	1	1
6	3	3	2	2	1	1
7	3	3	2	2	1	1
8	4	3	2	2	1	1
9	4	4	3	2	2	1
10	4	4	3	3	2	2
11	5	5	3	3	2	2
12	5	5	3	3	2	2
13	6	6	4	3	2	2
14	6	6	4	4	2	2
15	7	6	4	4	2	2
16	7	7	5	4	3	2
17	8	7	5	5	3	3
18	8	8	5	5	3	3
19	9	8	5	5	3	3
20	9	9	6	5	3	3
21	9	9	6	6	4	3
22	10	10	6	6	4	3
23	10	10	7	6	4	3
24	11	10	7	6	4	4
25	11	11	7	7	4	4
26	12	11	7	7	4	4
27	12	12	8	7	4	4
28	13	12	8	7	5	4
29	13	13	8	8	5	4
30	14	13	8	8	5	4
31	14	13	9	8	5	5
32	14	14	9	9	5	5
33	15	14	9	9	6	5
34	15	15	10	9	6	5
35	16	15	10	9	6	5
36	16	16	10	10	6	5
37	17	16	10	10	6	6
38	17	16	11	10	6	6
39	18	17	11	10	6	6
40	18	17	11	11	7	6
41	18	18	12	11	7	6
42	19	18	12	11	7	6
43	19	19	12	11	7	6
44	20	19	12	12	7	7
45	20	20	13	12	8	7
46	21	20	13	12	8	7
47	21	20	13	13	8	7
48	22	21	14	13	8	7
49	22	21	14	13	8	7
50	22	22	14	13	8	8
51	23	22	14	14	8	8
52	23	23	15	14	9	8
53	24	23	15	14	9	8
54	24	23	15	14	9	8
55	25	24	16	15	9	8
56	25	24	16	15	9	8
57	26	25	16	15	10	9
58	26	25	16	15	10	9
59	27	26	17	16	10	9
60	27	26	17	16	10	9
″	27	26	17	16	10	9

Proportional Parts

′	*l* sin 9.	d 1′	*l* csc 10.	*l* tan 9.	d 1′	*l* cot 10.	*l* sec 10.	d 1′	*l* cos 9.	′
0	78934	16	21066	89281	26	10719	10347	10	89653	60
1	950	17	050	307	26	693	357	10	643	59
2	967	16	033	333	26	667	367	9	633	58
3	983	16	017	359	26	641	376	10	624	57
4	999	16	001	385	26	615	386	10	614	56
5	79015	16	20985	411	26	589	396	10	604	55
6	031	16	969	437	26	563	406	10	594	54
7	047	16	953	463	26	537	416	10	584	53
8	063	16	937	489	26	511	426	10	574	52
9	079	16	921	515	26	485	436	10	564	51
10	095	16	905	541	26	459	446	10	554	50
11	111	17	889	567	26	433	456	10	544	49
12	128	16	872	593	26	407	466	10	534	48
13	144	16	856	619	26	381	476	10	524	47
14	160	16	840	645	26	355	486	10	514	46
15	176	16	824	671	26	329	496	9	504	45
16	192	16	808	697	26	303	505	10	495	44
17	208	16	792	723	26	277	515	10	485	43
18	224	16	776	749	26	251	525	10	475	42
19	240	16	760	775	26	225	535	10	465	41
20	256	16	744	801	26	199	545	10	455	40
21	272	16	728	827	26	173	555	10	445	39
22	288	16	712	853	26	147	565	10	435	38
23	304	15	696	879	26	121	575	10	425	37
24	319	16	681	905	26	095	585	10	415	36
25	335	16	665	931	26	069	595	10	405	35
26	351	16	649	957	26	043	605	10	395	34
27	367	16	633	983	26	017	615	10	385	33
28	383	16	617	90009	26	09991	625	11	375	32
29	399	16	601	035	26	965	636	10	364	31
30	79415	16	20585	90061	25	09939	10646	10	89354	30
31	431	16	569	086	26	914	656	10	344	29
32	447	16	553	112	26	888	666	10	334	28
33	463	15	537	138	26	862	676	10	324	27
34	478	16	522	164	26	836	686	10	314	26
35	494	16	506	190	26	810	696	10	304	25
36	510	16	490	216	26	784	706	10	294	24
37	526	16	474	242	26	758	716	10	284	23
38	542	16	458	268	26	732	726	10	274	22
39	558	15	442	294	26	706	736	10	264	21
40	573	16	427	320	26	680	746	10	254	20
41	589	16	411	346	25	654	756	11	244	19
42	605	16	395	371	26	629	767	10	233	18
43	621	15	379	397	26	603	777	10	223	17
44	636	16	364	423	26	577	787	10	213	16
45	652	16	348	449	26	551	797	10	203	15
46	668	16	332	475	26	525	807	10	193	14
47	684	15	316	501	26	499	817	10	183	13
48	699	16	301	527	26	473	827	11	173	12
49	715	16	285	553	25	447	838	10	162	11
50	731	15	269	578	26	422	848	10	152	10
51	746	16	254	604	26	396	858	10	142	9
52	762	16	238	630	26	370	868	10	132	8
53	778	15	222	656	26	344	878	10	122	7
54	793	16	207	682	26	318	888	11	112	6
55	809	16	191	708	26	292	899	10	101	5
56	825	15	175	734	25	266	909	10	091	4
57	840	16	160	759	26	241	919	10	081	3
58	856	16	144	785	26	215	929	11	071	2
59	872	15	128	811	26	189	940	10	060	1
60	79887		20113	90837		09163	10950		89050	0
′	9. *l* cos	d 1′	10. *l* sec	9. *l* cot	d 1′	10. *l* tan	10. *l* csc	d 1′	9. *l* sin	′

Proportional Parts

″	26	25	17	16	15	11	10	9
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
2	1	1	1	1	0	0	0	0
3	1	1	1	1	1	1	0	0
4	2	2	1	1	1	1	1	1
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6	3	2	2	2	2	1	1	1
7	3	3	2	2	2	1	1	1
8	3	3	2	2	2	1	1	1
9	4	4	3	2	2	2	2	1
10	4	4	3	3	2	2	2	2
11	5	5	3	3	3	2	2	2
12	5	5	3	3	3	2	2	2
13	6	5	4	3	3	2	2	2
14	6	6	4	4	4	3	2	2
15	6	6	4	4	4	3	2	2
16	7	7	5	4	4	3	3	2
17	7	7	5	5	4	3	3	3
18	8	8	5	5	4	3	3	3
19	8	8	5	5	5	3	3	3
20	9	8	6	5	5	4	3	3
21	9	9	6	6	5	4	4	3
22	10	9	6	6	6	4	4	3
23	10	10	7	6	6	4	4	3
24	10	10	7	6	6	4	4	4
25	11	10	7	7	6	5	4	4
26	11	11	7	7	6	5	4	4
27	12	11	8	7	7	5	4	4
28	12	12	8	7	7	5	5	4
29	13	12	8	8	7	5	5	4
30	13	12	8	8	8	6	5	4
31	13	13	9	8	8	6	5	5
32	14	13	9	9	8	6	5	5
33	14	14	9	9	8	6	6	5
34	15	14	10	9	8	6	6	5
35	15	15	10	9	9	6	6	5
36	16	15	10	10	9	7	6	5
37	16	15	10	10	9	7	6	6
38	16	16	11	10	10	7	6	6
39	17	16	11	10	10	7	6	6
40	17	17	11	11	10	7	7	6
41	18	17	12	11	10	8	7	6
42	18	18	12	11	10	8	7	6
43	19	18	12	11	11	8	7	6
44	19	18	12	12	11	8	7	7
45	20	19	13	12	11	8	8	7
46	20	19	13	12	12	8	8	7
47	20	20	13	13	12	9	8	7
48	21	20	14	13	12	9	8	7
49	21	20	14	13	12	9	8	7
50	22	21	14	13	12	9	8	8
51	22	21	14	14	13	9	8	8
52	23	22	15	14	13	10	9	8
53	23	22	15	14	13	10	9	8
54	23	22	15	14	14	10	9	8
55	24	23	16	15	14	10	9	8
56	24	23	16	15	14	10	9	8
57	25	24	16	15	14	10	10	9
58	25	24	16	15	14	11	10	9
59	26	25	17	16	15	11	10	9
60	26	25	17	16	15	11	10	9
″	26	25	17	16	15	11	10	9

Proportional Parts

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	79887	16	20113	90837	26	09163	10950	10	89050	60
1	903	15	097	863	26	137	960	10	040	59
2	918	16	082	889	25	111	970	10	030	58
3	934	16	066	914	26	086	980	11	020	57
4	950	15	050	940	26	060	991	10	009	56
5	965	16	035	966	26	034	11001	10	88999	55
6	981	15	019	992	26	008	011	11	989	54
7	996	16	004	91018	25	08982	022	10	978	53
8	80012	15	19988	043	26	957	032	10	968	52
9	027	16	973	069	26	931	042	10	958	51
10	043	15	957	095	26	905	052	11	948	50
11	058	16	942	121	26	879	063	10	937	49
12	074	15	926	147	25	853	073	10	927	48
13	089	16	911	172	26	828	083	11	917	47
14	105	15	895	198	26	802	094	10	906	46
15	120	16	880	224	26	776	104	10	896	45
16	136	15	864	250	26	750	114	11	886	44
17	151	15	849	276	25	724	125	10	875	43
18	166	16	834	301	26	699	135	10	865	42
19	182	15	818	327	26	673	145	11	855	41
20	197	16	803	353	26	647	156	10	844	40
21	213	15	787	379	25	621	166	10	834	39
22	228	16	772	404	26	596	176	11	824	38
23	244	15	756	430	26	570	187	10	813	37
24	259	15	741	456	26	544	197	10	803	36
25	274	16	726	482	25	518	207	11	793	35
26	290	15	710	507	26	493	218	10	782	34
27	305	15	695	533	26	467	228	11	772	33
28	320	16	680	559	26	441	239	10	761	32
29	336	15	664	585	25	415	249	10	751	31
30	80351	15	19649	91610	26	08390	11259	11	88741	30
31	366	16	634	636	26	364	270	10	730	29
32	382	15	618	662	26	338	280	11	720	28
33	397	15	603	688	25	312	291	10	709	27
34	412	16	588	713	26	287	301	11	699	26
35	428	15	572	739	26	261	312	10	688	25
36	443	15	557	765	26	235	322	10	678	24
37	458	15	542	791	25	209	332	11	668	23
38	473	16	527	816	26	184	343	10	657	22
39	489	15	511	842	26	158	353	11	647	21
40	504	15	496	868	25	132	364	10	636	20
41	519	15	481	893	26	107	374	11	626	19
42	534	16	466	919	26	081	385	10	615	18
43	550	15	450	945	26	055	395	11	605	17
44	565	15	435	971	25	029	406	10	594	16
45	580	15	420	996	26	004	416	11	584	15
46	595	15	405	92022	26	07978	427	10	573	14
47	610	15	390	048	25	952	437	11	563	13
48	625	16	375	073	26	927	448	10	552	12
49	641	15	359	099	26	901	458	11	542	11
50	656	15	344	125	25	875	469	10	531	10
51	671	15	329	150	26	850	479	11	521	9
52	686	15	314	176	26	824	490	11	510	8
53	701	15	299	202	25	798	501	10	499	7
54	716	15	284	227	26	773	511	11	489	6
55	731	15	269	253	26	747	522	10	478	5
56	746	16	254	279	25	721	532	11	468	4
57	762	15	238	304	26	696	543	10	457	3
58	777	15	223	330	26	670	553	11	447	2
59	792	15	208	356	25	644	564	11	436	1
60	80807		19193	92381		07619	11575		88425	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts 26	25	16	15	11	10
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	1	1	1	0	0	0
3	1	1	1	1	1	0
4	2	2	1	1	1	1
5	2	2	1	1	1	1
6	3	2	2	2	1	1
7	3	3	2	2	1	1
8	3	3	2	2	1	1
9	4	4	2	2	2	2
10	4	4	3	2	2	2
11	5	5	3	3	2	2
12	5	5	3	3	2	2
13	6	5	3	3	2	2
14	6	6	4	4	3	2
15	6	6	4	4	3	2
16	7	7	4	4	3	3
17	7	7	5	4	3	3
18	8	8	5	4	3	3
19	8	8	5	5	3	3
20	9	8	5	5	4	3
21	9	9	6	5	4	4
22	10	9	6	6	4	4
23	10	10	6	6	4	4
24	10	10	6	6	4	4
25	11	10	7	6	5	4
26	11	11	7	6	5	4
27	12	11	7	7	5	4
28	12	12	7	7	5	5
29	13	12	8	7	5	5
30	13	12	8	8	6	5
31	13	13	8	8	6	5
32	14	13	9	8	6	5
33	14	14	9	8	6	6
34	15	14	9	8	6	6
35	15	15	9	9	6	6
36	16	15	10	9	7	6
37	16	15	10	9	7	6
38	16	16	10	10	7	6
39	17	16	10	10	7	6
40	17	17	11	10	7	7
41	18	17	11	10	8	7
42	18	18	11	10	8	7
43	19	18	11	11	8	7
44	19	18	12	11	8	7
45	20	19	12	11	8	8
46	20	19	12	12	8	8
47	20	20	13	12	9	8
48	21	20	13	12	9	8
49	21	20	13	12	9	8
50	22	21	13	12	9	8
51	22	21	14	13	9	8
52	23	22	14	13	10	9
53	23	22	14	13	10	9
54	23	22	14	14	10	9
55	24	23	15	14	10	9
56	24	23	15	14	10	9
57	25	24	15	14	10	10
58	25	24	15	14	11	10
59	26	25	16	15	11	10
60	26	25	16	15	11	10
″	26	25	16	15	11	10
	Proportional Parts					

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	80807	15	19193	92381	26	07619	11575	10	88425	60
1	822	15	178	407	26	593	585	11	415	59
2	837	15	163	433	25	567	596	10	404	58
3	852	15	148	458	26	542	606	11	394	57
4	867	15	133	484	26	516	617	11	383	56
5	882	15	118	510	25	490	628	10	372	55
6	897	15	103	535	26	465	638	11	362	54
7	912	15	088	561	26	439	649	11	351	53
8	927	15	073	587	25	413	660	10	340	52
9	942	15	058	612	26	388	670	11	330	51
10	957	15	043	638	25	362	681	11	319	50
11	972	15	028	663	26	337	692	10	308	49
12	987	15	013	689	26	311	702	11	298	48
13	81002	15	18998	715	25	285	713	11	287	47
14	017	15	983	740	26	260	724	10	276	46
15	032	15	968	766	26	234	734	11	266	45
16	047	14	953	792	25	208	745	11	255	44
17	061	15	939	817	26	183	756	10	244	43
18	076	15	924	843	25	157	766	11	234	42
19	091	15	909	868	26	132	777	11	223	41
20	106	15	894	894	26	106	788	11	212	40
21	121	15	879	920	25	080	799	10	201	39
22	136	15	864	945	26	055	809	11	191	38
23	151	15	849	971	25	029	820	11	180	37
24	166	14	834	996	26	004	831	11	169	36
25	180	15	820	93022	26	06978	842	10	158	35
26	195	15	805	048	25	952	852	11	148	34
27	210	15	790	073	26	927	863	11	137	33
28	225	15	775	099	25	901	874	11	126	32
29	240	14	760	124	26	876	885	10	115	31
30	81254	15	18746	93150	25	06850	11895	11	88105	30
31	269	15	731	175	26	825	906	11	094	29
32	284	15	716	201	26	799	917	11	083	28
33	299	15	701	227	25	773	928	11	072	27
34	314	14	686	252	26	748	939	10	061	26
35	328	15	672	278	25	722	949	11	051	25
36	343	15	657	303	26	697	960	11	040	24
37	358	14	642	329	25	671	971	11	029	23
38	372	15	628	354	26	646	982	11	018	22
39	387	15	613	380	26	620	993	11	007	21
40	402	15	598	406	25	594	12004	11	87996	20
41	417	14	583	431	26	569	015	10	985	19
42	431	15	569	457	25	543	025	11	975	18
43	446	15	554	482	26	518	036	11	964	17
44	461	14	539	508	25	492	047	11	953	16
45	475	15	525	533	26	467	058	11	942	15
46	490	15	510	559	25	441	069	11	931	14
47	505	14	495	584	26	416	080	11	920	13
48	519	15	481	610	26	390	091	11	909	12
49	534	15	466	636	25	364	102	11	898	11
50	549	14	451	661	26	339	113	10	887	10
51	563	15	437	687	25	313	123	11	877	9
52	578	14	422	712	26	288	134	11	866	8
53	592	15	408	738	25	262	145	11	855	7
54	607	15	393	763	26	237	156	11	844	6
55	622	14	378	789	25	211	167	11	833	5
56	636	15	364	814	26	186	178	11	822	4
57	651	14	349	840	25	160	189	11	811	3
58	665	15	335	865	26	135	200	11	800	2
59	680	14	320	891	25	109	211	11	789	1
60	81694		18306	93916		06084	12222		87778	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts 26	25	15	14	11	10
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	1	1	0	0	0	0
3	1	1	1	1	1	0
4	2	2	1	1	1	1
5	2	2	1	1	1	1
6	3	2	2	1	1	1
7	3	3	2	2	1	1
8	3	3	2	2	1	1
9	4	4	2	2	2	2
10	4	4	2	2	2	2
11	5	5	3	3	2	2
12	5	5	3	3	2	2
13	6	5	3	3	2	2
14	6	6	4	3	3	2
15	6	6	4	4	3	2
16	7	7	4	4	3	3
17	7	7	4	4	3	3
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25	11	10	6	6	5	4
26	11	11	6	6	5	4
27	12	11	7	6	5	4
28	12	12	7	7	5	5
29	13	12	7	7	5	5
30	13	12	8	7	6	5
31	13	13	8	7	6	5
32	14	13	8	7	6	5
33	14	14	8	8	6	6
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42	18	18	10	10	8	7
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55	24	23	14	13	10	9
56	24	23	14	13	10	9
57	25	24	14	13	10	10
58	25	24	14	14	11	10
59	26	25	15	14	11	10
60	26	25	15	14	11	10
″	26 Proportional Parts	25	15	14	11	10

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	81694	15	18306	93916	26	06084	12222	11	87778	60
1	709	14	291	942	25	058	233	11	767	59
2	723	15	277	967	26	033	244	11	756	58
3	738	14	262	993	25	007	255	11	745	57
4	752	15	248	94018	26	05982	266	11	734	56
5	767	14	233	044	25	956	277	11	723	55
6	781	15	219	069	26	931	288	11	712	54
7	796	14	204	095	25	905	299	11	701	53
8	810	15	190	120	26	880	310	11	690	52
9	825	14	175	146	25	854	321	11	679	51
10	839	15	161	171	26	829	332	11	668	50
11	854	14	146	197	25	803	343	11	657	49
12	868	14	132	222	26	778	354	11	646	48
13	882	15	118	248	25	752	365	11	635	47
14	897	14	103	273	26	727	376	11	624	46
15	911	15	089	299	25	701	387	12	613	45
16	926	14	074	324	26	676	399	11	601	44
17	940	15	060	350	25	650	410	11	590	43
18	955	14	045	375	26	625	421	11	579	42
19	969	14	031	401	25	599	432	11	568	41
20	983	15	017	426	26	574	443	11	557	40
21	998	14	002	452	25	548	454	11	546	39
22	82012	14	17988	477	26	523	465	11	535	38
23	026	15	974	503	25	497	476	11	524	37
24	041	14	959	528	26	472	487	12	513	36
25	055	14	945	554	25	446	499	11	501	35
26	069	15	931	579	25	421	510	11	490	34
27	084	14	916	604	26	396	521	11	479	33
28	098	14	902	630	25	370	532	11	468	32
29	112	14	888	655	26	345	543	11	457	31
30	82126	15	17874	94681	25	05319	12554	12	87446	30
31	141	14	859	706	26	294	566	11	434	29
32	155	14	845	732	25	268	577	11	423	28
33	169	15	831	757	26	243	588	11	412	27
34	184	14	816	783	25	217	599	11	401	26
35	198	14	802	808	26	192	610	12	390	25
36	212	14	788	834	25	166	622	11	378	24
37	226	14	774	859	25	141	633	11	367	23
38	240	15	760	884	26	116	644	11	356	22
39	255	14	745	910	25	090	655	11	345	21
40	269	14	731	935	26	065	666	12	334	20
41	283	14	717	961	25	039	678	11	322	19
42	297	14	703	986	26	014	689	11	311	18
43	311	15	689	95012	25	04988	700	12	300	17
44	326	14	674	037	25	963	712	11	288	16
45	340	14	660	062	26	938	723	11	277	15
46	354	14	646	088	25	912	734	11	266	14
47	368	14	632	113	26	887	745	12	255	13
48	382	14	618	139	25	861	757	11	243	12
49	396	14	604	164	26	836	768	11	232	11
50	410	14	590	190	25	810	779	12	221	10
51	424	15	576	215	25	785	791	11	209	9
52	439	14	561	240	26	760	802	11	198	8
53	453	14	547	266	25	734	813	12	187	7
54	467	14	533	291	26	709	825	11	175	6
55	481	14	519	317	25	683	836	11	164	5
56	495	14	505	342	26	658	847	12	153	4
57	509	14	491	368	25	632	859	11	141	3
58	523	14	477	393	25	607	870	11	130	2
59	537	14	463	418	26	582	881	12	119	1
60	82551		17449	95444		04556	12893		87107	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	26	25	15	14	12	11
	Proportional Parts					
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	1	1	0	0	0	0
3	1	1	1	1	1	1
4	2	2	1	1	1	1
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22	10	9	6	5	4	4
23	10	10	6	5	5	4
24	10	10	6	6	5	4
25	11	10	6	6	5	5
26	11	11	6	6	5	5
27	12	11	7	6	5	5
28	12	12	7	7	6	5
29	13	12	7	7	6	5
30	13	12	8	7	6	6
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42	18	18	10	10	8	8
43	19	18	11	10	9	8
44	19	18	11	10	9	8
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55	24	23	14	13	11	10
56	24	23	14	13	11	10
57	25	24	14	13	11	10
58	25	24	14	14	12	11
59	26	25	15	14	12	11
60	26	25	15	14	12	11
″	26	25	15	14	12	11
	Proportional Parts					

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	82551	14	17449	95444	25	04556	12893	11	87107	60
1	565	14	435	469	26	531	904	11	096	59
2	579	14	421	495	25	505	915	12	085	58
3	593	14	407	520	25	480	927	11	073	57
4	607	14	393	545	26	455	938	12	062	56
5	621	14	379	571	25	429	950	11	050	55
6	635	14	365	596	26	404	961	11	039	54
7	649	14	351	622	25	378	972	12	028	53
8	663	14	337	647	25	353	984	11	016	52
9	677	14	323	672	26	328	995	12	005	51
10	691	14	309	698	25	302	13007	11	86993	50
11	705	14	295	723	25	277	018	12	982	49
12	719	14	281	748	26	252	030	11	970	48
13	733	14	267	774	25	226	041	12	959	47
14	747	14	253	799	26	201	053	11	947	46
15	761	14	239	825	25	175	064	12	936	45
16	775	13	225	850	25	150	076	11	924	44
17	788	14	212	875	26	125	087	11	913	43
18	802	14	198	901	25	099	098	12	902	42
19	816	14	184	926	26	074	110	11	890	41
20	830	14	170	952	25	048	121	12	879	40
21	844	14	156	977	25	023	133	12	867	39
22	858	14	142	96002	26	03998	145	11	855	38
23	872	13	128	028	25	972	156	12	844	37
24	885	14	115	053	25	947	168	11	832	36
25	899	14	101	078	26	922	179	12	821	35
26	913	14	087	104	25	896	191	11	809	34
27	927	14	073	129	26	871	202	12	798	33
28	941	14	059	155	25	845	214	11	786	32
29	955	13	045	180	25	820	225	12	775	31
30	82968	14	17032	96205	26	03795	13237	11	86763	30
31	982	14	018	231	25	769	248	12	752	29
32	996	14	004	256	25	744	260	12	740	28
33	83010	13	16990	281	26	719	272	11	728	27
34	023	14	977	307	25	693	283	12	717	26
35	037	14	963	332	25	668	295	11	705	25
36	051	14	949	357	26	643	306	12	694	24
37	065	13	935	383	25	617	318	12	682	23
38	078	14	922	408	25	592	330	11	670	22
39	092	14	908	433	26	567	341	12	659	21
40	106	14	894	459	25	541	353	12	647	20
41	120	13	880	484	26	516	365	11	635	19
42	133	14	867	510	25	490	376	12	624	18
43	147	14	853	535	25	465	388	12	612	17
44	161	13	839	560	26	440	400	11	600	16
45	174	14	826	586	25	414	411	12	589	15
46	188	14	812	611	25	389	423	12	577	14
47	202	13	798	636	26	364	435	11	565	13
48	215	14	785	662	25	338	446	12	554	12
49	229	13	771	687	25	313	458	12	542	11
50	242	14	758	712	26	288	470	12	530	10
51	256	14	744	738	25	262	482	11	518	9
52	270	13	730	763	25	237	493	12	507	8
53	283	14	717	788	26	212	505	12	495	7
54	297	13	703	814	25	186	517	11	483	6
55	310	14	690	839	25	161	528	12	472	5
56	324	14	676	864	26	136	540	12	460	4
57	338	13	662	890	25	110	552	12	448	3
58	351	14	649	915	25	085	564	11	436	2
59	365	13	635	940	26	060	575	12	425	1
60	83378		16622	96966		03034	13587		86413	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

″	Proportional Parts 26	25	14	13	12	11
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7	3	3	2	2	1	1
8	3	3	2	2	2	1
9	4	4	2	2	2	2
10	4	4	2	2	2	2
11	5	5	3	2	2	2
12	5	5	3	3	2	2
13	6	5	3	3	3	2
14	6	6	3	3	3	3
15	6	6	4	3	3	3
16	7	7	4	3	3	3
17	7	7	4	4	3	3
18	8	8	4	4	4	3
19	8	8	4	4	4	3
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22	10	9	5	5	4	4
23	10	10	5	5	5	4
24	10	10	6	5	5	4
25	11	10	6	5	5	5
26	11	11	6	6	5	5
27	12	11	6	6	5	5
28	12	12	7	6	6	5
29	13	12	7	6	6	5
30	13	12	7	6	6	6
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33	14	14	8	7	7	6
34	15	14	8	7	7	6
35	15	15	8	8	7	6
36	16	15	8	8	7	7
37	16	15	9	8	7	7
38	16	16	9	8	8	7
39	17	16	9	8	8	7
40	17	17	9	9	8	7
41	18	17	10	9	8	8
42	18	18	10	9	8	8
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45	20	19	10	10	9	8
46	20	19	11	10	9	8
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55	24	23	13	12	11	10
56	24	23	13	12	11	10
57	25	24	13	12	11	10
58	25	24	14	13	12	11
59	26	25	14	13	12	11
60	26	25	14	13	12	11
″	26 Proportional Parts	25	14	13	12	11

′	l sin 9.	d 1′	l csc 10.	l tan 9.	d 1′	l cot 10.	l sec 10.	d 1′	l cos 9.	′
0	83378	14	16622	96966	25	03034	13587	12	86413	60
1	392	13	608	991	25	009	599	12	401	59
2	405	14	595	97016	26	02984	611	12	389	58
3	419	13	581	042	25	958	623	11	377	57
4	432	14	568	067	25	933	634	12	366	56
5	446	13	554	092	26	908	646	12	354	55
6	459	14	541	118	25	882	658	12	342	54
7	473	13	527	143	25	857	670	12	330	53
8	486	14	514	168	25	832	682	12	318	52
9	500	13	500	193	26	807	694	11	306	51
10	513	14	487	219	25	781	705	12	295	50
11	527	13	473	244	25	756	717	12	283	49
12	540	14	460	269	26	731	729	12	271	48
13	554	13	446	295	25	705	741	12	259	47
14	567	14	433	320	25	680	753	12	247	46
15	581	13	419	345	26	655	765	12	235	45
16	594	14	406	371	25	629	777	12	223	44
17	608	13	392	396	25	604	789	11	211	43
18	621	13	379	421	26	579	800	12	200	42
19	634	14	366	447	25	553	812	12	188	41
20	648	13	352	472	25	528	824	12	176	40
21	661	13	339	497	26	503	836	12	164	39
22	674	14	326	523	25	477	848	12	152	38
23	688	13	312	548	25	452	860	12	140	37
24	701	14	299	573	25	427	872	12	128	36
25	715	13	285	598	26	402	884	12	116	35
26	728	13	272	624	25	376	896	12	104	34
27	741	14	259	649	25	351	908	12	092	33
28	755	13	245	674	26	326	920	12	080	32
29	768	13	232	700	25	300	932	12	068	31
30	83781	14	16219	97725	25	02275	13944	12	86056	30
31	795	13	205	750	26	250	956	12	044	29
32	808	13	192	776	25	224	968	12	032	28
33	821	13	179	801	25	199	980	12	020	27
34	834	14	166	826	25	174	992	12	008	26
35	848	13	152	851	26	149	14004	12	85996	25
36	861	13	139	877	25	123	016	12	984	24
37	874	13	126	902	25	098	028	12	972	23
38	887	14	113	927	26	073	040	12	960	22
39	901	13	099	953	25	047	052	12	948	21
40	914	13	086	978	25	022	064	12	936	20
41	927	13	073	98003	26	01997	076	12	924	19
42	940	14	060	029	25	971	088	12	912	18
43	954	13	046	054	25	946	100	12	900	17
44	967	13	033	079	25	921	112	12	888	16
45	980	13	020	104	26	896	124	12	876	15
46	993	13	007	130	25	870	136	13	864	14
47	84006	14	15994	155	25	845	149	12	851	13
48	020	13	980	180	26	820	161	12	839	12
49	033	13	967	206	25	794	173	12	827	11
50	046	13	954	231	25	769	185	12	815	10
51	059	13	941	256	25	744	197	12	803	9
52	072	13	928	281	26	719	209	12	791	8
53	085	13	915	307	25	693	221	13	779	7
54	098	14	902	332	25	668	234	12	766	6
55	112	13	888	357	26	643	246	12	754	5
56	125	13	875	383	25	617	258	12	742	4
57	138	13	862	408	25	592	270	12	730	3
58	151	13	849	433	25	567	282	12	718	2
59	164	13	836	458	26	542	294	13	706	1
60	84177		15823	98484		01516	14307		85693	0
′	9. l cos	d 1′	10. l sec	9. l cot	d 1′	10. l tan	10. l csc	d 1′	9. l sin	′

Proportional Parts

″	26	25	14	13	12	11
0	0	0	0	0	0	0
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2	1	1	0	0	0	0
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12	5	5	3	3	2	2
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28	12	12	7	6	6	5
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43	19	18	10	9	9	8
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46	20	19	11	10	9	8
47	20	20	11	10	9	9
48	21	20	11	10	10	9
49	21	20	11	11	10	9
50	22	21	12	11	10	9
51	22	21	12	11	10	9
52	23	22	12	11	10	10
53	23	22	12	11	11	10
54	23	22	13	12	11	10
55	24	23	13	12	11	10
56	24	23	13	12	11	10
57	25	24	13	12	11	10
58	25	24	14	13	12	11
59	26	25	14	13	12	11
60	26	25	14	13	12	11
″	26	25	14	13	12	11

Proportional Parts

′	*l* sin 9.	d 1′	*l* csc 10.	*l* tan 9.	d 1′	*l* cot 10.	*l* sec 10.	d 1′	*l* cos 9.	′
0	84177	13	15823	98484	25	01516	14307	12	85693	60
1	190	13	810	509	25	491	319	12	681	59
2	203	13	797	534	26	466	331	12	669	58
3	216	13	784	560	25	440	343	12	657	57
4	229	13	771	585	25	415	355	13	645	56
5	242	13	758	610	25	390	368	12	632	55
6	255	14	745	635	26	365	380	12	620	54
7	269	13	731	661	25	339	392	12	608	53
8	282	13	718	686	25	314	404	13	596	52
9	295	13	705	711	26	289	417	12	583	51
10	308	13	692	737	25	263	429	12	571	50
11	321	13	679	762	25	238	441	12	559	49
12	334	13	666	787	25	213	453	13	547	48
13	347	13	653	812	26	188	466	12	534	47
14	360	13	640	838	25	162	478	12	522	46
15	373	12	627	863	25	137	490	13	510	45
16	385	13	615	888	25	112	503	12	497	44
17	398	13	602	913	26	087	515	12	485	43
18	411	13	589	939	25	061	527	13	473	42
19	424	13	576	964	25	036	540	12	460	41
20	437	13	563	989	26	011	552	12	448	40
21	450	13	550	99015	25	00985	564	13	436	39
22	463	13	537	040	25	960	577	12	423	38
23	476	13	524	065	25	935	589	12	411	37
24	489	13	511	090	26	910	601	13	399	36
25	502	13	498	116	25	884	614	12	386	35
26	515	13	485	141	25	859	626	13	374	34
27	528	12	472	166	25	834	639	12	361	33
28	540	13	460	191	26	809	651	12	349	32
29	553	13	447	217	25	783	663	13	337	31
30	84566	13	15434	99242	25	00758	14676	12	85324	30
31	579	13	421	267	26	733	688	13	312	29
32	592	13	408	293	25	707	701	12	299	28
33	605	13	395	318	25	682	713	13	287	27
34	618	12	382	343	25	657	726	12	274	26
35	630	13	370	368	26	632	738	12	262	25
36	643	13	357	394	25	606	750	13	250	24
37	656	13	344	419	25	581	763	12	237	23
38	669	13	331	444	25	556	775	13	225	22
39	682	12	318	469	26	531	788	12	212	21
40	694	13	306	495	25	505	800	13	200	20
41	707	13	293	520	25	480	813	12	187	19
42	720	13	280	545	25	455	825	13	175	18
43	733	12	267	570	26	430	838	12	162	17
44	745	13	255	596	25	404	850	13	150	16
45	758	13	242	621	25	379	863	12	137	15
46	771	13	229	646	26	354	875	13	125	14
47	784	12	216	672	25	328	888	12	112	13
48	796	13	204	697	25	303	900	13	100	12
49	809	13	191	722	25	278	913	13	087	11
50	822	13	178	747	26	253	926	12	074	10
51	835	12	165	773	25	227	938	13	062	9
52	847	13	153	798	25	202	951	12	049	8
53	860	13	140	823	25	177	963	13	037	7
54	873	12	127	848	26	152	976	12	024	6
55	885	13	115	874	25	126	988	13	012	5
56	898	13	102	899	25	101	15001	13	84999	4
57	911	12	089	924	25	076	014	12	986	3
58	923	13	077	949	26	051	026	13	974	2
59	936	13	064	975	25	025	039	12	961	1
60	84949		15051	00000		00000	15051		84949	0
′	9. *l* cos	d 1′	10. *l* sec	10. *l* cot	d 1′	10. *l* tan	10. *l* csc	d 1′	9. *l* sin	′

Proportional Parts

″	26	25	14	13	12
0	0	0	0	0	0
1	0	0	0	0	0
2	1	1	0	0	0
3	1	1	1	1	1
4	2	2	1	1	1
5	2	2	1	1	1
6	3	2	1	1	1
7	3	3	2	2	1
8	3	3	2	2	2
9	4	4	2	2	2
10	4	4	2	2	2
11	5	5	3	2	2
12	5	5	3	3	2
13	6	5	3	3	3
14	6	6	3	3	3
15	6	6	4	3	3
16	7	7	4	3	3
17	7	7	4	4	3
18	8	8	4	4	4
19	8	8	4	4	4
20	9	8	5	4	4
21	9	9	5	5	4
22	10	9	5	5	4
23	10	10	5	5	5
24	10	10	6	5	5
25	11	10	6	5	5
26	11	11	6	6	5
27	12	11	6	6	5
28	12	12	7	6	6
29	13	12	7	6	6
30	13	12	7	6	6
31	13	13	7	7	6
32	14	13	7	7	6
33	14	14	8	7	7
34	15	14	8	7	7
35	15	15	8	8	7
36	16	15	8	8	7
37	16	15	9	8	7
38	16	16	9	8	8
39	17	16	9	8	8
40	17	17	9	9	8
41	18	17	10	9	8
42	18	18	10	9	8
43	19	18	10	9	9
44	19	18	10	10	9
45	20	19	10	10	9
46	20	19	11	10	9
47	20	20	11	10	9
48	21	20	11	10	10
49	21	20	11	11	10
50	22	21	12	11	10
51	22	21	12	11	10
52	23	22	12	11	10
53	23	22	12	11	11
54	23	22	13	12	11
55	24	23	13	12	11
56	24	23	13	12	11
57	25	24	13	12	11
58	25	24	14	13	12
59	26	25	14	13	12
60	26	25	14	13	12
″	26	25	14	13	12

Proportional Parts

TABLE III

NATURAL TRIGONOMETRIC FUNCTIONS

This table gives the values of the trigonometric functions to five places of decimals for every minute of arc. For each tabular difference in the main table are listed, under proportional parts (P.P.), the following values.

1. Increment for each second from 1 to 10 seconds.
2. Increment for each 10 seconds from 10 to 50 seconds.

Example 1. To find the natural sine of 44°10′39″. The sine of 44°10′, which appears in the main table, is .69675. The next tabular difference, which is given in Column d of the main table, is 21. In the table of proportional parts, under 21, the increment for 30″ is 10.5 and that for 9″ is 3.2. Adding 10.5 and 3.2 to .69675, the value sought is obtained, .62689.

This may be tabulated as follows.

Source	Angle	Tabular values	d
Main table	44°10′	.69675	21
P.P. for 21	30″	10.5	
P.P. for 21	9″	3.2	
Adding gives the value sought		.69689	

Example 2. To find the angle having the natural sine .62019. The value in the main table just smaller than .62019 is .62001, which is the sine of 38°19′. The tabular difference is 23. The remainder, .62019 less .62001, is 18. The value in the table of proportional parts just smaller than 18 is 15.3, which is the increment for 40″. The second remainder, 18 less 15.3, is 2.7. The value in the table of proportional parts nearest 2.7 is 2.7, which is the increment for 7″. Adding 40″ and 7″ to 38°19′, the value sought is obtained, 38°19′47″.

This may be tabulated as follows.

Source	Tabular values	d	Angles
Given	.62019		
Main table	.62001	23	38°19′
Remainder	18		
P.P. for 23	15.3		40″
Second remainder	2.7		
P.P. for 23	2.7		7″
Adding gives the value sought			38°19′47″

0°

P. P.

	30
1	0.5
2	1.0
3	1.5
4	2.0
5	2.5
6	3.0
7	3.5
8	4.0
9	4.5
10	5.0
20	10.0
30	15.0
40	20.0
50	25.0

	29
1	0.5
2	1.0
3	1.4
4	1.9
5	2.4
6	2.9
7	3.4
8	3.9
9	4.4
10	4.8
20	9.7
30	14.5
40	19.3
50	24.2

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.00000	29	1.0000	0	.00000	29	∞		**60**
1	029	29	000	0	029	29	3437.7	1718.8	59
2	058	29	000	0	058	29	1718.9	573.0	58
3	087	29	000	0	087	29	1145.9	286.46	57
4	116	29	000	0	116	29	859.44	171.89	56
5	.00145	30	1.0000	0	.00145	30	687.55	114.59	**55**
6	175	29	000	0	175	29	572.96	81.85	54
7	204	29	000	0	204	29	491.11	61.39	53
8	233	29	000	0	233	29	429.72	47.75	52
9	262	29	000	0	262	29	381.97	38.20	51
10	.00291	29	1.0000	1	.00291	29	343.77	31.25	**50**
11	320	29	.99999	0	320	29	312.52	26.04	49
12	349	29	999	0	349	29	286.48	22.04	48
13	378	29	999	0	378	29	264.44	18.89	47
14	407	29	999	0	407	29	245.55	16.37	46
15	.00436	29	.99999	0	.00436	29	229.18	14.32	**45**
16	465	30	999	0	465	30	214.86	12.64	44
17	495	29	999	0	495	29	202.22	11.24	43
18	524	29	999	1	524	29	190.98	10.05	42
19	553	29	998	0	553	29	180.93	9.04	41
20	.00582	29	.99998	0	.00582	29	171.89	8.19	**40**
21	611	29	998	0	611	29	163.70	7.44	39
22	640	29	998	0	640	29	156.26	6.79	38
23	669	29	998	0	669	29	149.47	6.23	37
24	698	29	998	1	698	29	143.24	5.73	36
25	.00727	29	.99997	0	.00727	29	137.51	5.29	**35**
26	756	29	997	0	756	29	132.22	4.90	34
27	785	29	997	0	785	30	127.32	4.55	33
28	814	30	997	1	815	29	122.77	4.23	32
29	844	29	996	0	844	29	118.54	3.95	31
30	.00873	29	.99996	0	.00873	29	114.59	3.70	**30**
31	902	29	996	0	902	29	110.89	3.46	29
32	931	29	996	1	931	29	107.43	3.26	28
33	960	29	995	0	960	29	104.17	3.06	27
34	989	29	995	0	989	29	101.11	2.892	26
35	.01018	29	.99995	0	.01018	29	98.218	2.729	**25**
36	047	29	995	1	047	29	95.489	2.581	24
37	076	29	994	0	076	29	92.908	2.445	23
38	105	29	994	0	105	30	90.463	2.319	22
39	134	30	994	1	135	29	88.144	2.204	21
40	.01164	29	.99993	0	.01164	29	85.940	2.096	**20**
41	193	29	993	0	193	29	83.844	1.997	19
42	222	29	993	1	222	29	81.847	1.904	18
43	251	29	992	0	251	29	79.943	1.817	17
44	280	29	992	1	280	29	78.126	1.736	16
45	.01309	29	.99991	0	.01309	29	76.390	1.661	**15**
46	338	29	991	0	338	29	74.729	1.590	14
47	367	29	991	1	367	29	73.139	1.524	13
48	396	29	990	0	396	29	71.615	1.462	12
49	425	29	990	1	425	30	70.153	1.403	11
50	.01454	29	.99989	0	.01455	29	68.750	1.348	**10**
51	483	30	989	0	484	29	67.402	1.297	9
52	513	29	989	1	513	29	66.105	1.247	8
53	542	29	988	0	542	29	64.858	1.201	7
54	571	29	988	1	571	29	63.657	1.158	6
55	.01600	29	.99987	0	.01600	29	62.499	1.116	**5**
56	629	29	987	1	629	29	61.383	1.077	4
57	658	29	986	0	658	29	60.306	1.040	3
58	687	29	986	1	687	29	59.266	1.005	2
59	716	29	985	0	716	30	58.261	.971	1
60	.01745		.99985		.01746		57.290		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d	′

P. P.

89°

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1°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	′
0	.01745	29	.99985	1	.01746	29	57.290	939	60
1	774	29	984	0	775	29	56.351	909	59
2	803	29	984	1	804	29	55.442	881	58
3	832	30	983	0	833	29	54.561	852	57
4	862	29	983	1	862	29	53.709	827	56
5	.01891	29	.99982	0	.01891	29	52.882	801	55
6	920	29	982	1	920	29	.081	778	54
7	949	29	981	1	949	29	51.303	754	53
8	978	29	980	0	978	29	50.549	733	52
9	.02007	29	980	1	.02007	29	49.816	712	51
10	.02036	29	.99979	0	.02036	30	49.104	692	50
11	065	29	979	1	066	29	48.412	672	49
12	094	29	978	1	095	29	47.740	655	48
13	123	29	977	0	124	29	.085	636	47
14	152	29	977	1	153	29	46.449	620	46
15	.02181	30	.99976	0	.02182	29	45.829	603	45
16	211	29	976	1	211	29	.226	587	44
17	240	29	975	1	240	29	44.639	573	43
18	269	29	974	0	269	29	.066	558	42
19	298	29	974	1	298	30	43.508	544	41
20	.02327	29	.99973	1	.02328	29	42.964	531	40
21	356	29	972	0	357	29	.433	517	39
22	385	29	972	1	386	29	41.916	505	38
23	414	29	971	1	415	29	.411	494	37
24	443	29	970	1	444	29	40.917	481	36
25	.02472	29	.99969	0	.02473	29	40.436	471	35
26	501	29	969	1	502	29	39.965	459	34
27	530	30	968	1	531	29	.506	449	33
28	560	29	967	1	560	29	.057	439	32
29	589	29	966	0	589	30	38.618	430	31
30	.02618	29	.99966	1	.02619	29	38.188	419	30
31	647	29	965	1	648	29	37.769	411	29
32	676	29	964	1	677	29	.358	402	28
33	705	29	963	0	706	29	36.956	393	27
34	734	29	963	1	735	29	.563	385	26
35	.02763	29	.99962	1	.02764	29	36.178	377	25
36	792	29	961	1	793	29	35.801	370	24
37	821	29	960	1	822	29	.431	361	23
38	850	29	959	0	851	30	.070	355	22
39	879	29	959	1	881	29	34.715	347	21
40	.02908	30	.99958	1	.02910	29	34.368	341	20
41	938	29	957	1	939	29	.027	333	19
42	967	29	956	1	968	29	33.694	328	18
43	996	29	955	1	997	29	.366	321	17
44	.03025	29	954	1	.03026	29	.045	315	16
45	.03054	29	.99953	1	.03055	29	32.730	309	15
46	083	29	952	0	084	30	.421	303	14
47	112	29	952	1	114	29	.118	297	13
48	141	29	951	1	143	29	31.821	293	12
49	170	29	950	1	172	29	.528	286	11
50	.03199	29	.99949	1	.03201	29	31.242	282	10
51	228	29	948	1	230	29	30.960	277	9
52	257	29	947	1	259	29	.683	271	8
53	286	30	946	1	288	29	.412	267	7
54	316	29	945	1	317	29	.145	263	6
55	.03345	29	.99944	1	.03346	30	29.882	258	5
56	374	29	943	1	376	29	.624	253	4
57	403	29	942	1	405	29	.371	249	3
58	432	29	941	1	434	29	.122	245	2
59	461	29	940	1	463	29	28.877	241	1
60	.03490		.99939		.03492		28.636		0
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

P. P.

	30	29
1	0.5	0.5
2	1.0	1.0
3	1.5	1.4
4	2.0	1.9
5	2.5	2.4
6	3.0	2.9
7	3.5	3.4
8	4.0	3.9
9	4.5	4.4
10	5.0	4.8
20	10.0	9.7
30	15.0	14.5
40	20.0	19.3
50	25.0	24.2

88°

2°

P. P.	′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
	0	.03490	29	.99939	1	.03492	29	28.636	237	**60**
	1	519	29	938	1	521	29	.399	233	59
	2	548	29	937	1	550	29	.166	229	58
	3	577	29	936	1	579	30	27.937	225	57
	4	606	29	935	1	609	29	.712	222	56
	5	.03635	29	.99934	1	.03638	29	27.490	219	**55**
	6	664	29	933	1	667	29	.271	214	54
	7	693	30	932	1	696	29	.057	212	53
	8	723	29	931	1	725	29	26.845	208	52
	9	752	29	930	1	754	29	.637	205	51
	10	.03781	29	.99929	2	.03783	29	26.432	202	**50**
	11	810	29	927	1	812	30	.230	199	49
	12	839	29	926	1	842	29	.031	196	48
	13	868	29	925	1	871	29	25.835	193	47
	14	897	29	924	1	900	29	.642	190	46
	15	.03926	29	.99923	1	.03929	29	25.452	188	**45**
	16	955	29	922	1	958	29	.264	184	44
	17	984	29	921	2	987	29	.080	182	43
	18	.04013	29	919	1	.04016	30	24.898	179	42
	19	042	29	918	1	046	29	.719	177	41
	20	.04071	29	.99917	1	.04075	29	24.542	174	**40**
	21	100	29	916	1	104	29	.368	172	39
2	22	129	30	915	2	133	29	.196	170	38
1 | 0.0	23	159	29	913	1	162	29	.026	167	37
2 | 0.1	24	188	29	912	1	191	29	23.859	164	36
3 | 0.1	**25**	.04217	29	.99911	1	.04220	30	23.695	163	**35**
4 | 0.1	26	246	29	910	1	250	29	.532	160	34
5 | 0.2	27	275	29	909	2	279	29	.372	158	33
6 | 0.2	28	304	29	907	1	308	29	.214	156	32
7 | 0.2	29	333	29	906	1	337	29	.058	154	31
8 | 0.3	**30**	.04362	29	.99905	1	.04366	29	22.904	152	**30**
9 | 0.3	31	391	29	904	2	395	29	.752	150	29
10 | 0.3	32	420	29	902	1	424	30	.602	148	28
20 | 0.7	33	449	29	901	1	454	29	.454	146	27
30 | 1.0	34	478	29	900	2	483	29	.308	144	26
40 | 1.3	**35**	.04507	29	.99898	1	.04512	29	22.164	142	**25**
50 | 1.7	36	536	29	897	1	541	29	.022	141	24
	37	565	29	896	2	570	29	21.881	138	23
	38	594	29	894	1	599	29	.743	137	22
	39	623	30	893	1	628	30	.606	136	21
	40	.04653	29	.99892	2	.04658	29	21.470	133	**20**
	41	682	29	890	1	687	29	.337	132	19
	42	711	29	889	1	716	29	.205	130	18
	43	740	29	888	2	745	29	.075	129	17
	44	769	29	886	1	774	29	20.946	127	16
	45	.04798	29	.99885	2	.04803	30	20.819	126	**15**
	46	827	29	883	1	833	29	.693	124	14
	47	856	29	882	1	862	29	.569	123	13
	48	885	29	881	2	891	29	.446	121	12
	49	914	29	879	1	920	29	.325	119	11
	50	.04943	29	.99878	2	.04949	29	20.206	119	**10**
	51	972	29	876	1	978	29	.087	117	9
	52	.05001	29	875	2	.05007	30	19.970	115	8
	53	030	29	873	1	037	29	.855	115	7
	54	059	29	872	2	066	29	.740	113	6
	55	.05088	29	.99870	1	.05095	29	19.627	111	**5**
	56	117	29	869	2	124	29	.516	111	4
	57	146	29	867	1	153	29	.405	109	3
	58	175	30	866	2	182	30	.296	108	2
	59	205	29	864	1	212	29	.188	107	1
	60	.05234		.99863		.05241		19.081		**0**
P. P.		Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

87°

3°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.05234	29	.99863	2	.05241	29	19.081	105	**60**
1	263	29	861	1	270	29	18.976	105	59
2	292	29	860	2	299	29	.871	103	58
3	321	29	858	1	328	29	.768	102	57
4	350	29	857	2	357	30	.666	102	56
5	.05379	29	.99855	1	.05387	29	18.564	100	**55**
6	408	29	854	2	416	29	.464	98	54
7	437	29	852	1	445	29	.366	98	53
8	466	29	851	2	474	29	.268	97	52
9	495	29	849	2	503	30	.171	96	51
10	.05524	29	.99847	1	.05533	29	18.075	95	**50**
11	553	29	846	2	562	29	17.980	94	49
12	582	29	844	2	591	29	.886	93	48
13	611	29	842	1	620	29	.793	91	47
14	640	29	841	2	649	29	.702	91	46
15	.05669	29	.99839	1	.05678	30	17.611	90	**45**
16	698	29	838	2	708	29	.521	90	44
17	727	29	836	2	737	29	.431	88	43
18	756	29	834	1	766	29	.343	87	42
19	785	29	833	2	795	29	.256	87	41
20	.05814	30	.99831	2	.05824	30	17.169	85	**40**
21	844	29	829	2	854	29	.084	85	39
22	873	29	827	1	883	29	16.999	84	38
23	902	29	826	2	912	29	.915	83	37
24	931	29	824	2	941	29	.832	82	36
25	.05960	29	.99822	1	.05970	29	16.750	82	**35**
26	989	29	821	2	999	30	.668	81	34
27	.06018	29	819	2	.06029	29	.587	80	33
28	047	29	817	2	058	29	.507	79	32
29	076	29	815	2	087	29	.428	78	31
30	.06105	29	.99813	1	.06116	29	16.350	78	**30**
31	134	29	812	2	145	30	.272	77	29
32	163	29	810	2	175	29	.195	76	28
33	192	29	808	2	204	29	.119	76	27
34	221	29	806	2	233	29	.043	74	26
35	.06250	29	.99804	1	.06262	29	15.969	74	**25**
36	279	29	803	2	291	30	.895	74	24
37	308	29	801	2	321	29	.821	73	23
38	337	29	799	2	350	29	.748	72	22
39	366	29	797	2	379	29	.676	71	21
40	.06395	29	.99795	2	.06408	30	15.605	71	**20**
41	424	29	793	1	438	29	.534	70	19
42	453	29	792	2	467	29	.464	70	18
43	482	29	790	2	496	29	.394	69	17
44	511	29	788	2	525	29	.325	68	16
45	.06540	29	.99786	2	.06554	30	15.257	68	**15**
46	569	29	784	2	584	29	.189	67	14
47	598	29	782	2	613	29	.122	66	13
48	627	29	780	2	642	29	.056	66	12
49	656	29	778	2	671	29	14.990	66	11
50	.06685	29	.99776	2	.06700	30	14.924	64	**10**
51	714	29	774	2	730	29	.860	65	9
52	743	30	772	2	759	29	.795	63	8
53	773	29	770	2	788	29	.732	63	7
54	802	29	768	2	817	30	.669	63	6
55	.06831	29	.99766	2	.06847	29	14.606	62	**5**
56	860	29	764	2	876	29	.544	62	4
57	889	29	762	2	905	29	.482	61	3
58	918	29	760	2	934	29	.421	60	2
59	947	29	758	2	963	30	.361	60	1
60	.06976		.99756		.06993		14.301		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

86°

P. P.

	30	29
1	0.5	0.5
2	1.0	1.0
3	1.5	1.4
4	2.0	1.9
5	2.5	2.4
6	3.0	2.9
7	3.5	3.4
8	4.0	3.9
9	4.5	4.4
10	5.0	4.8
20	10.0	9.7
30	15.0	14.5
40	20.0	19.3
50	25.0	24.2

P. P.

4°

P. P.

	3	2
1	0.0	0.0
2	0.1	0.1
3	0.2	0.1
4	0.2	0.1
5	0.2	0.2
6	0.3	0.2
7	0.4	0.2
8	0.4	0.3
9	0.4	0.3
10	0.5	0.3
20	1.0	0.7
30	1.5	1.0
40	2.0	1.3
50	2.5	1.7

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.06976	29	.99756	2	.06993	29	14.301	60	**60**
1	.07005	29	754	2	.07022	29	.241	59	59
2	034	29	752	2	051	29	.182	58	58
3	063	29	750	2	080	30	.124	59	57
4	092	29	748	2	110	29	.065	57	56
5	.07121	29	.99746	2	.07139	29	14.008	57	**55**
6	150	29	744	2	168	29	13.951	57	54
7	179	29	742	2	197	30	.894	56	53
8	208	29	740	2	227	29	.838	56	52
9	237	29	738	2	256	29	.782	55	51
10	.07266	29	.99736	2	.07285	29	13.727	55	**50**
11	295	29	734	3	314	30	.672	55	49
12	324	29	731	2	344	29	.617	54	48
13	353	29	729	2	373	29	.563	53	47
14	382	29	727	2	402	29	.510	53	46
15	.07411	29	.99725	2	.07431	30	13.457	53	**45**
16	440	29	723	2	461	29	.404	52	44
17	469	29	721	2	490	29	.352	52	43
18	498	29	719	3	519	29	.300	52	42
19	527	29	716	2	548	30	.248	51	41
20	.07556	29	.99714	2	.07578	29	13.197	51	**40**
21	585	29	712	2	607	29	.146	50	39
22	614	29	710	2	636	29	.096	50	38
23	643	29	708	3	665	30	.046	50	37
24	672	29	705	2	695	29	12.996	49	36
25	.07701	29	.99703	2	.07724	29	12.947	49	**35**
26	730	29	701	2	753	29	.898	48	34
27	759	29	699	3	782	30	.850	49	33
28	788	29	696	2	812	29	.801	47	32
29	817	29	694	2	841	29	.754	48	31
30	.07846	29	.99692	3	.07870	29	12.706	47	**30**
31	875	29	689	2	899	30	.659	47	29
32	904	29	687	2	929	29	.612	46	28
33	933	29	685	2	958	29	.566	46	27
34	962	29	683	3	987	30	.520	46	26
35	.07991	29	.99680	2	.08017	29	12.474	45	**25**
36	.08020	29	678	2	046	29	.429	45	24
37	049	29	676	3	075	29	.384	45	23
38	078	29	673	2	104	30	.339	44	22
39	107	29	671	3	134	29	.295	44	21
40	.08136	29	.99668	2	.08163	29	12.251	44	**20**
41	165	29	666	2	192	29	.207	44	19
42	194	29	664	3	221	30	.163	43	18
43	223	29	661	2	251	29	.120	43	17
44	252	29	659	2	280	29	.077	42	16
45	.08281	29	.99657	3	.08309	30	12.035	43	**15**
46	310	29	654	2	339	29	11.992	42	14
47	339	29	652	3	368	29	.950	41	13
48	368	29	649	2	397	30	.909	42	12
49	397	29	647	3	427	29	.867	41	11
50	.08426	29	.99644	2	.08456	29	11.826	41	**10**
51	455	29	642	3	485	29	.785	40	9
52	484	29	639	2	514	30	.745	40	8
53	513	29	637	2	544	29	.705	41	7
54	542	29	635	3	573	29	.664	39	6
55	.08571	29	.99632	2	.08602	30	11.625	40	**5**
56	600	29	630	3	632	29	.585	39	4
57	629	29	627	2	661	29	.546	39	3
58	658	29	625	3	690	30	.507	39	2
59	687	29	622	3	720	29	.468	38	1
60	.08716		.99619		.08749		11.430		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

P. P.

85°

5°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.08716	29	.99619	2	.08749	29	11.430	38	**60**
1	745	29	617	3	778	29	.392	38	59
2	774	29	614	2	807	30	.354	38	58
3	803	28	612	3	837	28	.316	37	57
4	831	29	609	2	866	29	.279	37	56
5	.08860	29	.99607	3	.08895	30	11.242	37	**55**
6	889	29	604	2	925	29	.205	37	54
7	918	29	602	3	954	29	.168	36	53
8	947	29	599	3	983	30	.132	37	52
9	976	29	596	2	.09013	29	.095	36	51
10	.09005	29	.99594	3	.09042	29	11.059	35	**50**
11	034	29	591	3	071	30	.024	36	49
12	063	29	588	2	101	29	10.988	35	48
13	092	29	586	3	130	29	.953	35	47
14	121	29	583	3	159	30	.918	35	46
15	.09150	29	.99580	2	.09189	29	10.883	35	**45**
16	179	29	578	3	218	29	.848	34	44
17	208	29	575	3	247	30	.814	34	43
18	237	29	572	2	277	29	.780	34	42
19	266	29	570	3	306	29	.746	34	41
20	.09295	29	.99567	3	.09335	30	10.712	34	**40**
21	324	29	564	2	365	29	.678	33	39
22	353	29	562	3	394	29	.645	33	38
23	382	29	559	3	423	30	.612	33	37
24	411	29	556	3	453	29	.579	33	36
25	.09440	29	.99553	2	.09482	29	10.546	32	**35**
26	469	29	551	3	511	30	.514	33	34
27	498	29	548	3	541	29	.481	32	33
28	527	29	545	3	570	30	.449	32	32
29	556	29	542	2	600	29	.417	32	31
30	.09585	29	.99540	3	.09629	29	10.385	31	**30**
31	614	28	537	3	658	30	.354	32	29
32	642	29	534	3	688	29	.322	31	28
33	671	29	531	3	717	29	.291	31	27
34	700	29	528	2	746	30	.260	31	26
35	.09729	29	.99526	3	.09776	29	10.229	30	**25**
36	758	29	523	3	805	29	.199	31	24
37	787	29	520	3	834	30	.168	30	23
38	816	29	517	3	864	29	.138	30	22
39	845	29	514	3	893	30	.108	30	21
40	.09874	29	.99511	3	.09923	29	10.078	30	**20**
41	903	29	508	2	952	29	.048	29	19
42	932	29	506	3	981	30	.019	297	18
43	961	29	503	3	.10011	29	9.9893	292	17
44	990	29	500	3	040	29	.9601	291	16
45	.10019	29	.99497	3	.10069	30	9.9310	289	**15**
46	048	29	494	3	099	29	.9021	287	14
47	077	29	491	3	128	30	.8734	286	13
48	106	29	488	3	158	29	.8448	284	12
49	135	29	485	3	187	29	.8164	282	11
50	.10164	28	.99482	3	.10216	30	9.7882	281	**10**
51	192	29	479	3	246	29	.7601	279	9
52	221	29	476	3	275	30	.7322	278	8
53	250	29	473	3	305	29	.7044	276	7
54	279	29	470	3	334	29	.6768	275	6
55	.10308	29	.99467	3	.10363	30	9.6493	273	**5**
56	337	29	464	3	393	29	.6220	271	4
57	366	29	461	3	422	30	.5949	270	3
58	395	29	458	3	452	29	.5679	268	2
59	424	29	455	3	481	29	.5411	267	1
60	.10453		.99452		.10510		9.5144		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

84°

P. P.

	30	29
1	0.5	0.5
2	1.0	1.0
3	1.5	1.4
4	2.0	1.9
5	2.5	2.4
6	3.0	2.9
7	3.5	3.4
8	4.0	3.9
9	4.5	4.4
10	5.0	4.8
20	10.0	9.7
30	15.0	14.5
40	20.0	19.3
50	25.0	24.2

	28	4
1	0.5	0.1
2	0.9	0.1
3	1.4	0.2
4	1.9	0.3
5	2.3	0.3
6	2.8	0.4
7	3.3	0.5
8	3.7	0.5
9	4.2	0.6
10	4.7	0.7
20	9.3	1.3
30	14.0	2.0
40	18.7	2.7
50	23.3	3.3

P. P.

6°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.10453	29	.99452	3	.10510	30	9.5144	266	**60**
1	482	29	449	3	540	29	.4878	264	59
2	511	29	446	3	569	30	.4614	262	58
3	540	29	443	3	599	29	.4352	262	57
4	569	28	440	3	628	29	.4090	259	56
5	.10597	29	.99437	3	.10657	30	9.3831	259	**55**
6	626	29	434	3	687	29	.3572	257	54
7	655	29	431	3	716	30	.3315	255	53
8	684	29	428	4	746	29	.3060	254	52
9	713	29	424	3	775	30	.2806	253	51
10	.10742	29	.99421	3	.10805	29	9.2553	251	**50**
11	771	29	418	3	834	29	.2302	250	49
12	800	29	415	3	863	30	.2052	249	48
13	829	29	412	3	893	29	.1803	248	47
14	858	29	409	3	922	30	.1555	246	46
15	.10887	29	.99406	4	.10952	29	9.1309	244	**45**
16	916	29	402	3	981	30	.1065	244	44
17	945	28	399	3	.11011	29	.0821	242	43
18	973	29	396	3	040	30	.0579	241	42
19	.11002	29	393	3	070	29	.0338	240	41
20	.11031	29	.99390	4	.11099	29	9.0098	238	**40**
21	060	29	386	3	128	30	8.9860	237	39
22	089	29	383	3	158	29	.9623	236	38
23	118	29	380	3	187	30	.9387	235	37
24	147	29	377	3	217	29	.9152	233	36
25	.11176	29	.99374	4	.11246	30	8.8919	233	**35**
26	205	29	370	3	276	29	.8686	231	34
27	234	29	367	3	305	30	.8455	230	33
28	263	28	364	4	335	29	.8225	229	32
29	291	29	360	3	364	30	.7996	227	31
30	.11320	29	.99357	3	.11394	29	8.7769	227	**30**
31	349	29	354	3	423	29	.7542	225	29
32	378	29	351	4	452	30	.7317	224	28
33	407	29	347	3	482	29	.7093	223	27
34	436	29	344	3	511	30	.6870	222	26
35	.11465	29	.99341	4	.11541	29	8.6648	221	**25**
36	494	29	337	3	570	30	.6427	219	24
37	523	29	334	3	600	29	.6208	219	23
38	552	28	331	4	629	30	.5989	217	22
39	580	29	327	3	659	29	.5772	217	21
40	.11609	29	.99324	4	.11688	30	8.5555	215	**20**
41	638	29	320	3	718	29	.5340	214	19
42	667	29	317	3	747	30	.5126	213	18
43	696	29	314	4	777	29	.4913	212	17
44	725	29	310	3	806	30	.4701	211	16
45	.11754	29	.99307	4	.11836	29	8.4490	210	**15**
46	783	29	303	3	865	30	.4280	209	14
47	812	28	300	3	895	29	.4071	208	13
48	840	29	297	4	924	30	.3863	207	12
49	869	29	293	3	954	29	.3656	206	11
50	.11898	29	.99290	4	.11983	30	8.3450	205	**10**
51	927	29	286	3	.12013	29	.3245	204	9
52	956	29	283	4	042	30	.3041	203	8
53	985	29	279	3	072	29	.2838	202	7
54	.12014	29	276	4	101	30	.2636	202	6
55	12043	28	.99272	3	.12131	29	8.2434	200	**5**
56	071	29	269	4	160	30	.2234	199	4
57	100	29	265	3	190	29	.2035	198	3
58	129	29	262	4	219	30	.1837	197	2
59	158	29	258	3	249	29	.1640	197	1
60	.12187		.99255		.12278		8.1443		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

P. P.

	3	2
1	0.0	0.0
2	0.1	0.1
3	0.2	0.1
4	0.2	0.1
5	0.2	0.2
6	0.3	0.2
7	0.4	0.2
8	0.4	0.3
9	0.4	0.3
10	0.5	0.3
20	1.0	0.7
30	1.5	1.0
40	2.0	1.3
50	2.5	1.7

83°

7°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	′
0	.12187	29	.99255	4	.12278	30	8.1443	195	**60**
1	216	29	251	3	308	30	.1248	194	59
2	245	29	248	4	338	29	.1054	194	58
3	274	28	244	4	367	30	.0860	193	57
4	302	29	240	3	397	29	.0667	191	56
5	.12331	29	.99237	4	.12426	30	8.0476	191	**55**
6	360	29	233	3	456	29	.0285	190	54
7	389	29	230	4	485	30	.0095	189	53
8	418	29	226	4	515	29	7.9906	188	52
9	447	29	222	3	544	30	.9718	188	51
10	.12476	28	.99219	4	.12574	29	7.9530	186	**50**
11	504	29	215	4	603	30	.9344	186	49
12	533	29	211	3	633	29	.9158	185	48
13	562	29	208	4	662	30	.8973	184	47
14	591	29	204	4	692	30	.8789	183	46
15	.12620	29	.99200	3	.12722	29	7.8606	182	**45**
16	649	29	197	4	751	30	.8424	181	44
17	678	28	193	4	781	29	.8243	181	43
18	706	29	189	3	810	30	.8062	180	42
19	735	29	186	4	840	29	.7882	178	41
20	.12764	29	.99182	4	.12869	30	7.7704	179	**40**
21	793	29	178	3	899	30	.7525	177	39
22	822	29	175	4	929	29	.7348	177	38
23	851	29	171	4	958	30	.7171	175	37
24	880	28	167	4	988	29	.6996	175	36
25	.12908	29	.99163	3	.13017	30	7.6821	174	**35**
26	937	29	160	4	047	29	.6647	174	34
27	966	29	156	4	076	30	.6473	172	33
28	995	29	152	4	106	30	.6301	172	32
29	.13024	29	148	4	136	29	.6129	171	31
30	.13053	28	.99144	3	.13165	30	7.5958	171	**30**
31	081	29	141	4	195	29	.5787	169	29
32	110	29	137	4	224	30	.5618	169	28
33	139	29	133	4	254	30	.5449	168	27
34	168	29	129	4	284	29	.5281	168	26
35	.13197	29	.99125	3	.13313	30	7.5113	166	**25**
36	226	28	122	4	343	29	.4947	166	24
37	254	29	118	4	372	30	.4781	166	23
38	283	29	114	4	402	30	.4615	164	22
39	312	29	110	4	432	29	.4451	164	21
40	.13341	29	.99106	4	.13461	30	7.4287	163	**20**
41	370	29	102	4	491	30	.4124	162	19
42	399	28	098	4	521	29	.3962	162	18
43	427	29	094	3	550	30	.3800	161	17
44	456	29	091	4	580	29	.3639	160	16
45	.13485	29	.99087	4	.13609	30	7.3479	160	**15**
46	514	29	083	4	639	30	.3319	159	14
47	543	29	079	4	669	29	.3160	158	13
48	572	28	075	4	698	30	.3002	158	12
49	600	29	071	4	728	30	.2844	157	11
50	.13629	29	.99067	4	.13758	29	7.2687	156	**10**
51	658	29	063	4	787	30	.2531	156	9
52	687	29	059	4	817	29	.2375	155	8
53	716	28	055	4	846	30	.2220	154	7
54	744	29	051	4	876	30	.2066	154	6
55	.13773	29	.99047	4	.13906	29	7.1912	153	**5**
56	802	29	043	4	935	30	.1759	152	4
57	831	29	039	4	965	30	.1607	152	3
58	860	29	035	4	995	29	.1455	151	2
59	889	28	031	4	.14024	30	.1304	150	1
60	.13917		.99027		.14054		7.1154		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

82°

P. P.

	30	29
1	0.5	0.5
2	1.0	1.0
3	1.5	1.4
4	2.0	1.9
5	2.5	2.4
6	3.0	2.9
7	3.5	3.4
8	4.0	3.9
9	4.5	4.4
10	5.0	4.8
20	10.0	9.7
30	15.0	14.5
40	20.0	19.3
50	25.0	24.2

	28	5
1	0.5	0.1
2	0.9	0.2
3	1.4	0.2
4	1.9	0.3
5	2.3	0.4
6	2.8	0.5
7	3.3	0.6
8	3.7	0.7
9	4.2	0.8
10	4.7	0.8
20	9.3	1.7
30	14.0	2.5
40	18.7	3.3
50	23.3	4.2

P. P.

8°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.13917	29	.99027	4	.14054	30	7.1154	150	**60**
1	946	29	023	4	084	29	.1004	149	59
2	975	29	019	4	113	30	.0855	149	58
3	.14004	29	015	4	143	30	.0706	148	57
4	033	28	011	5	173	29	.0558	148	56
5	.14061	29	.99006	4	.14202	30	7.0410	146	**55**
6	090	29	002	4	232	30	.0264	147	54
7	119	29	.98998	4	262	29	.0117	145	53
8	148	29	994	4	291	30	6.9972	145	52
9	177	28	990	4	321	30	.9827	145	51
10	.14205	29	.98986	4	.14351	30	6.9682	144	**50**
11	234	29	982	4	381	29	.9538	143	49
12	263	29	978	5	410	30	.9395	143	48
13	292	28	973	4	440	30	.9252	142	47
14	320	29	969	4	470	29	.9110	141	46
15	.14349	29	.98965	4	.14499	30	6.8969	141	**45**
16	378	29	961	4	529	30	.8828	141	44
17	407	29	957	4	559	29	.8687	139	43
18	436	28	953	5	588	30	.8548	140	42
19	464	29	948	4	618	30	.8408	139	41
20	.14493	29	.98944	4	.14648	30	6.8269	138	**40**
21	522	29	940	4	678	29	.8131	137	39
22	551	29	936	5	707	30	.7994	138	38
23	580	28	931	4	737	30	.7856	136	37
24	608	29	927	4	767	29	.7720	136	36
25	.14637	29	.98923	4	.14796	30	6.7584	136	**35**
26	666	29	919	5	826	30	.7448	135	34
27	695	28	914	4	856	30	.7313	134	33
28	723	29	910	4	886	29	.7179	134	32
29	752	29	906	4	915	30	.7045	133	31
30	.14781	29	.98902	5	.14945	30	6.6912	133	**30**
31	810	28	897	4	975	30	.6779	133	29
32	838	29	893	4	.15005	29	.6646	132	28
33	867	29	889	5	034	30	.6514	131	27
34	896	29	884	4	064	30	.6383	131	26
35	.14925	29	.98880	4	.15094	30	6.6252	130	**25**
36	954	28	876	5	124	29	.6122	130	24
37	982	29	871	4	153	30	.5992	129	23
38	.15011	29	867	4	183	30	.5863	129	22
39	040	29	863	5	213	30	.5734	128	21
40	.15069	28	.98858	4	.15243	29	6.5606	128	**20**
41	097	29	854	5	272	30	.5478	128	19
42	126	29	849	4	302	30	.5350	127	18
43	155	29	845	4	332	30	.5223	126	17
44	184	28	841	5	362	29	.5097	126	16
45	.15212	29	.98836	4	.15391	30	6.4971	125	**15**
46	241	29	832	5	421	30	.4846	125	14
47	270	29	827	4	451	30	.4721	125	13
48	299	28	823	5	481	30	.4596	124	12
49	327	29	818	4	511	29	.4472	124	11
50	.15356	29	.98814	5	.15540	30	6.4348	123	**10**
51	385	29	809	4	570	30	.4225	122	9
52	414	28	805	5	600	30	.4103	123	8
53	442	29	800	4	630	30	.3980	121	7
54	471	29	796	5	660	29	.3859	122	6
55	.15500	29	.98791	4	.15689	30	6.3737	120	**5**
56	529	28	787	5	719	30	.3617	121	4
57	557	29	782	4	749	30	.3496	120	3
58	586	29	778	5	779	30	.3376	119	2
59	615	28	773	4	809	29	.3257	119	1
60	.15643		.98769		.15838		6.3138		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

81°

P. P.

	4	3
1	0.1	0.0
2	0.1	0.1
3	0.2	0.2
4	0.3	0.2
5	0.3	0.2
6	0.4	0.3
7	0.5	0.4
8	0.5	0.4
9	0.6	0.4
10	0.7	0.5
20	1.3	1.0
30	2.0	1.5
40	2.7	2.0
50	3.3	2.5

9°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.15643	29	.98769	5	.15838	30	6.3138	119	**60**
1	672	29	764	4	868	30	.3019	118	59
2	701	29	760	5	898	30	.2901	118	58
3	730	28	755	4	928	30	.2783	117	57
4	758	29	751	5	958	30	.2666	117	56
5	.15787	29	.98746	5	.15988	29	6.2549	117	**55**
6	816	29	741	4	.16017	30	.2432	116	54
7	845	28	737	5	047	30	.2316	116	53
8	873	29	732	4	077	30	.2200	115	52
9	902	29	728	5	107	30	.2085	115	51
10	.15931	28	.98723	5	.16137	30	6.1970	114	**50**
11	959	29	718	4	167	29	.1856	114	49
12	988	29	714	5	196	30	.1742	114	48
13	.16017	29	709	5	226	30	.1628	113	47
14	046	28	704	4	256	30	.1515	113	46
15	.16074	29	.98700	5	.16286	30	6.1402	112	**45**
16	103	29	695	5	316	30	.1290	112	44
17	132	28	690	4	346	30	.1178	112	43
18	160	29	686	5	376	29	.1066	111	42
19	189	29	681	5	405	30	.0955	111	41
20	.16218	28	.98676	5	.16435	30	6.0844	110	**40**
31	246	29	671	4	465	30	.0734	110	39
22	275	29	667	5	495	30	.0624	110	38
23	304	29	662	5	525	30	.0514	109	37
24	333	28	657	5	555	30	.0405	109	36
25	.16361	29	.98652	4	.16585	30	6.0296	108	**35**
26	390	29	648	5	615	30	.0188	108	34
27	419	28	643	5	645	29	.0080	108	33
28	447	29	638	5	674	30	5.9972	107	32
29	476	29	633	4	704	30	.9865	107	31
30	.16505	28	.98629	5	.16734	30	5.9758	107	**30**
31	533	29	624	5	764	30	.9651	106	29
32	562	29	619	5	794	30	.9545	106	28
33	591	29	614	5	824	30	.9439	106	27
34	620	28	609	5	854	30	.9333	105	26
35	.16648	29	.98604	4	.16884	30	5.9228	104	**25**
36	677	29	600	5	914	30	.9124	105	24
37	706	28	595	5	944	30	.9019	104	23
38	734	29	590	5	974	30	.8915	104	22
39	763	29	585	5	.17004	29	.8811	103	21
40	.16792	28	.98580	5	.17033	30	5.8708	103	**20**
41	820	29	575	5	063	30	.8605	103	19
42	849	29	570	5	093	30	.8502	102	18
43	878	28	565	4	123	30	.8400	102	17
44	906	29	561	5	153	30	.8298	101	16
45	.16935	29	.98556	5	.17183	30	5.8197	102	**15**
46	964	28	551	5	213	30	.8095	101	14
47	992	29	546	5	243	30	.7994	100	13
48	.17021	29	541	5	273	30	.7894	100	12
49	050	28	536	5	303	30	.7794	100	11
50	.17078	29	.98531	5	.17333	30	5.7694	100	**10**
51	107	29	526	5	363	30	.7594	99	9
52	136	28	521	5	393	30	.7495	99	8
53	164	29	516	5	423	30	.7396	99	7
54	193	29	511	5	453	30	.7297	98	6
55	.17222	28	.98506	5	.17483	30	5.7199	98	**5**
56	250	29	501	5	513	30	.7101	97	4
57	279	29	496	5	543	30	.7004	98	3
58	308	28	491	5	573	30	.6906	97	2
59	336	29	486	5	603	30	.6809	96	1
60	.17365		.98481		.17633		5.6713		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

80°

P. P.

	31	30
1	0.5	0.5
2	1.0	1.0
3	1.6	1.5
4	2.1	2.0
5	2.6	2.5
6	3.1	3.0
7	3.6	3.5
8	4.1	4.0
9	4.6	4.5
10	5.2	5.0
20	10.3	10.0
30	15.5	15.0
40	20.7	20.0
50	25.8	25.0

	29	28
1	0.5	0.5
2	1.0	0.9
3	1.4	1.4
4	1.9	1.9
5	2.4	2.3
6	2.9	2.8
7	3.4	3.3
8	3.9	3.7
9	4.4	4.2
10	4.8	4.7
20	9.7	9.3
30	14.5	14.0
40	19.3	18.7
50	24.2	23.3

P. P.

10°

P. P.

	6	5
1	0.1	0.1
2	0.2	0.2
3	0.3	0.2
4	0.4	0.3
5	0.5	0.4
6	0.6	0.5
7	0.7	0.6
8	0.8	0.7
9	0.9	0.8
10	1.0	0.8
20	2.0	1.7
30	3.0	2.5
40	4.0	3.3
50	5.0	4.2

	4
1	0.1
2	0.1
3	0.2
4	0.3
5	0.3
6	0.4
7	0.5
8	0.5
9	0.6
10	0.7
20	1.3
30	2.0
40	2.7
50	3.3

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.17365	28	.98481	5	.17633	30	5.6713	96	**60**
1	393	29	476	5	663	30	.6617	96	59
2	422	29	471	5	693	30	.6521	96	58
3	451	28	466	5	723	30	.6425	96	57
4	479	29	461	6	753	30	.6329	95	56
5	.17508	29	.98455	5	.17783	30	5.6234	94	**55**
6	537	28	450	5	813	30	.6140	95	54
7	565	29	445	5	843	30	.6045	94	53
8	594	29	440	5	873	30	.5951	94	52
9	623	28	435	5	903	30	.5857	93	51
10	.17651	29	.98430	5	.17933	30	5.5764	93	**50**
11	680	28	425	5	963	30	.5671	93	49
12	708	29	420	6	993	30	.5578	93	48
13	737	29	414	5	.18023	30	.5485	92	47
14	766	28	409	5	053	30	.5393	92	46
15	.17794	29	.98404	5	.18083	30	5.5301	92	**45**
16	823	29	399	5	113	30	.5209	91	44
17	852	28	394	5	143	30	.5118	92	43
18	880	29	389	6	173	30	.5026	90	42
19	909	28	383	5	203	30	.4936	91	41
20	.17937	29	.98378	5	.18233	30	5.4845	90	**40**
21	966	29	373	5	263	30	.4755	90	39
22	995	28	368	6	293	30	.4665	90	38
23	.18023	29	362	5	323	30	.4575	89	37
24	052	29	357	5	353	31	.4486	89	36
25	.18081	28	.98352	5	.18384	30	5.4397	89	**35**
26	109	29	347	6	414	30	.4308	89	34
27	138	28	341	5	444	30	.4219	88	33
28	166	29	336	5	474	30	.4131	88	32
29	195	29	331	6	504	30	.4043	88	31
30	.18224	28	.98325	5	.18534	30	5.3955	87	**30**
31	252	29	320	5	564	30	.3868	87	29
32	281	28	315	5	594	30	.3781	87	28
33	309	29	310	6	624	30	.3694	87	27
34	338	29	304	5	654	30	.3607	86	26
35	.18367	28	.98299	5	.18684	30	5.3521	86	**25**
36	395	29	294	6	714	31	.3435	86	24
37	424	28	288	5	745	30	.3349	86	23
38	452	29	283	6	775	30	.3263	85	22
39	481	28	277	5	805	30	.3178	85	21
40	.18509	29	.98272	5	.18835	30	5.3093	85	**20**
41	538	29	267	6	865	30	.3008	84	19
42	567	28	261	5	895	30	.2924	85	18
43	595	29	256	6	925	30	.2839	84	17
44	624	28	250	5	955	31	.2755	83	16
45	.18652	29	.98245	5	.18986	30	5.2672	84	**15**
46	681	29	240	6	.19016	30	.2588	83	14
47	710	28	234	5	046	30	.2505	83	13
48	738	29	229	6	076	30	.2422	83	12
49	767	28	223	5	106	30	.2339	82	11
50	.18795	29	.98218	6	.19136	30	5.2257	83	**10**
51	824	28	212	5	166	31	.2174	82	9
52	852	29	207	6	197	30	.2092	81	8
53	881	29	201	5	227	30	.2011	82	7
54	910	28	196	6	257	30	.1929	81	6
55	.18938	29	.98190	5	.19287	30	5.1848	81	**5**
56	967	28	185	6	317	30	.1767	81	4
57	995	29	179	5	347	31	.1686	80	3
58	.19024	28	174	6	378	30	.1606	80	2
59	052	29	168	5	408	30	.1526	80	1
60	.19081		.98163		.19438		5.1446		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

P. P.

79°

11°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	′
0	.19081	28	.98163	6	.19438	30	5.1446	80	**60**
1	109	29	157	5	468	30	.1366	80	59
2	138	29	152	6	498	31	.1286	79	58
3	167	28	146	6	529	30	.1207	79	57
4	195	29	140	5	559	30	.1128	79	56
5	.19224	28	.98135	6	.19589	30	5.1049	79	**55**
6	252	29	129	5	619	30	.0970	78	54
7	281	28	124	6	649	31	.0892	78	53
8	309	29	118	6	680	30	.0814	78	52
9	338	28	112	5	710	30	.0736	78	51
10	.19366	29	.98107	6	.19740	30	5.0658	77	**50**
11	395	28	101	5	770	31	.0581	77	49
12	423	29	096	6	801	30	.0504	77	48
13	452	29	090	6	831	30	.0427	77	47
14	481	28	084	5	861	30	.0350	77	46
15	.19509	29	.98079	6	.19891	30	5.0273	76	**45**
16	538	28	073	6	921	31	.0197	76	44
17	566	29	067	6	952	30	.0121	76	43
18	595	28	061	5	982	30	.0045	76	42
19	623	29	056	6	.20012	30	4.9969	75	41
20	.19652	28	.98050	6	.20042	31	4.9894	75	**40**
21	680	29	044	5	073	30	.9819	75	39
22	709	28	039	6	103	30	.9744	75	38
23	737	29	033	6	133	31	.9669	75	37
24	766	28	027	6	164	30	.9594	74	36
25	.19794	29	.98021	5	.20194	30	4.9520	74	**35**
26	823	28	016	6	224	30	.9446	74	34
27	851	29	010	6	254	31	.9372	74	33
28	880	28	004	6	285	30	.9298	73	32
29	908	29	.97998	6	315	30	.9225	73	31
30	.19937	28	.97992	5	.20345	31	4.9152	74	**30**
31	965	29	987	6	376	30	.9078	72	29
32	994	28	981	6	406	30	.9006	73	28
33	.20022	29	975	6	436	30	.8933	73	27
34	051	28	969	6	466	31	.8860	72	26
35	.20079	29	.97963	5	.20497	30	4.8788	72	**25**
36	108	28	958	6	527	30	.8716	72	24
37	136	29	952	6	557	31	.8644	71	23
38	165	28	946	6	588	30	.8573	72	22
39	193	29	940	6	618	30	.8501	71	21
40	.20222	28	.97934	6	.20648	31	4.8430	71	**20**
41	250	29	928	6	679	30	.8359	71	19
42	279	28	922	6	709	30	.8288	70	18
43	307	29	916	6	739	31	.8218	71	17
44	336	28	910	5	770	30	.8147	70	16
45	.20364	29	.97905	6	.20800	30	4.8077	70	**15**
46	393	28	899	6	830	31	.8007	70	14
47	421	29	893	6	861	30	.7937	70	13
48	450	28	887	6	891	30	.7867	69	12
49	478	29	881	6	921	31	.7798	69	11
50	.20507	28	.97875	6	.20952	30	4.7729	70	**10**
51	535	28	869	6	982	31	.7659	68	9
52	563	29	863	6	.21013	30	.7591	69	8
53	592	28	857	6	043	30	.7522	69	7
54	620	29	851	6	073	31	.7453	68	6
55	.20649	28	.97845	6	.21104	30	4.7385	68	**5**
56	677	29	839	6	134	30	.7317	68	4
57	706	28	833	6	164	31	.7249	68	3
58	734	29	827	6	195	30	.7181	67	2
59	763	28	821	6	225	31	.7114	68	1
60	.20791		.97815		.21256		4.7046		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

78°

P. P.

	31	**30**
1	0.5	0.5
2	1.0	1.0
3	1.6	1.5
4	2.1	2.0
5	2.6	2.5
6	3.1	3.0
7	3.6	3.5
8	4.1	4.0
9	4.6	4.5
10	5.2	5.0
20	10.3	10.0
30	15.5	15.0
40	20.7	20.0
50	25.8	25.0

	29	**28**
1	0.5	0.5
2	1.0	0.9
3	1.4	1.4
4	1.9	1.9
5	2.4	2.3
6	2.9	2.8
7	3.4	3.3
8	3.9	3.7
9	4.4	4.2
10	4.8	4.7
20	9.7	9.3
30	14.5	14.0
40	19.3	18.7
50	24.2	23.3

P. P.

12°

P. P.

	7	6
1	0.1	0.1
2	0.2	0.2
3	0.4	0.3
4	0.5	0.4
5	0.6	0.5
6	0.7	0.6
7	0.8	0.7
8	0.9	0.8
9	1.0	0.9
10	1.2	1.0
20	2.3	2.0
30	3.5	3.0
40	4.7	4.0
50	5.8	5.0

	5
1	0.1
2	0.2
3	0.2
4	0.3
5	0.4
6	0.5
7	0.6
8	0.7
9	0.8
10	0.8
20	1.7
30	2.5
40	3.3
50	4.2

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.20791	29	.97815	6	.21256	30	4.7046	67	**60**
1	820	28	809	6	286	30	.6979	67	59
2	848	29	803	6	316	31	.6912	67	58
3	877	28	797	6	347	30	.6845	66	57
4	905	28	791	7	377	31	.6779	67	56
5	.20933	29	.97784	6	.21408	30	4.6712	66	**55**
6	962	28	778	6	438	31	.6646	66	54
7	990	29	772	6	469	30	.6580	66	53
8	.21019	28	766	6	499	30	.6514	66	52
9	047	29	760	6	529	31	.6448	66	51
10	.21076	28	.97754	6	.21560	30	4.6382	65	**50**
11	104	28	748	6	590	31	.6317	65	49
12	132	29	742	7	621	30	.6252	65	48
13	161	28	735	6	651	31	.6187	65	47
14	189	29	729	6	682	30	.6122	65	46
15	.21218	28	.97723	6	.21712	31	4.6057	64	**45**
16	246	29	717	6	743	30	.5993	65	44
17	275	28	711	6	773	31	.5928	64	43
18	303	28	705	7	804	30	.5864	64	42
19	331	29	698	6	834	30	.5800	64	41
20	.21360	28	.97692	6	.21864	31	4.5736	63	**40**
21	388	29	686	6	895	30	.5673	64	39
22	417	28	680	7	925	31	.5609	63	38
23	445	29	673	6	956	30	.5546	63	37
24	474	28	667	6	986	31	.5483	63	36
25	.21502	28	.97661	6	.22017	30	4.5420	63	**35**
26	530	29	655	7	047	31	.5357	63	34
27	559	28	648	6	078	30	.5294	62	33
28	587	29	642	6	108	31	.5232	63	32
29	616	28	636	6	139	30	.5169	62	31
30	.21644	28	.97630	7	.22169	31	4.5107	62	**30**
31	672	29	623	6	200	31	.5045	62	29
32	701	28	617	6	231	30	.4983	61	28
33	729	29	611	7	261	31	.4922	62	27
34	758	28	604	6	292	30	.4860	61	26
35	.21786	28	.97598	6	.22322	31	4.4799	62	**25**
36	814	29	592	7	353	30	.4737	61	24
37	843	28	585	6	383	31	.4676	61	23
38	871	28	579	6	414	30	.4615	60	22
39	899	29	573	7	444	31	.4555	61	21
40	.21928	28	.97566	6	.22475	30	4.4494	60	**20**
41	956	29	560	7	505	31	.4434	61	19
42	985	28	553	6	536	31	.4373	60	18
43	.22013	28	547	6	567	30	.4313	60	17
44	041	29	541	7	597	31	.4253	59	16
45	.22070	28	.97534	6	.22628	30	4.4194	60	**15**
46	098	28	528	7	658	31	.4134	59	14
47	126	29	521	6	689	30	.4075	60	13
48	155	28	515	7	719	31	.4015	59	12
49	183	29	508	6	750	31	.3956	59	11
50	.22212	28	.97502	6	.22781	30	4.3897	59	**10**
51	240	28	496	7	811	31	.3838	59	9
52	268	29	489	6	842	30	.3779	58	8
53	297	28	483	7	872	31	.3721	59	7
54	325	28	476	6	903	31	.3662	58	6
55	.22353	29	.97470	7	.22934	30	4.3604	58	**5**
56	382	28	463	6	964	31	.3546	58	4
57	410	28	457	7	995	31	.3488	58	3
58	438	29	450	6	.23026	30	.3430	58	2
59	467	28	444	7	056	31	.3372	57	1
60	.22495		.97437		.23087		4.3315		**0**
	Cos.	**d.**	**Sin.**	**d.**	**Cot.**	**d.**	**Tan.**	**d.**	**′**

P. P.

77°

13°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.22495	28	.97437	7	.23087	30	4.3315	58	**60**
1	523	29	430	6	117	31	.3257	57	59
2	552	28	424	7	148	31	.3200	57	58
3	580	28	417	6	179	30	.3143	57	57
4	608	29	411	7	209	31	.3086	57	56
5	.22637	28	.97404	6	.23240	31	4.3029	57	**55**
6	665	28	398	7	271	30	.2972	56	54
7	693	29	391	7	301	31	.2916	57	53
8	722	28	384	6	332	31	.2859	56	52
9	750	28	378	7	363	30	.2803	56	51
10	.22778	29	.97371	6	.23393	31	4.2747	56	**50**
11	807	28	365	7	424	31	.2691	56	49
12	835	28	358	7	455	30	.2635	55	48
13	863	29	351	6	485	31	.2580	56	47
14	892	28	345	7	516	31	.2524	56	46
15	.22920	28	.97338	7	.23547	31	4.2468	55	**45**
16	948	29	331	6	578	30	.2413	55	44
17	977	28	325	7	608	31	.2358	55	43
18	.23005	28	318	7	639	31	.2303	55	42
19	033	29	311	7	670	30	.2248	55	41
20	.23062	28	.97304	6	.23700	31	4.2193	54	**40**
21	090	28	298	7	731	31	.2139	55	39
22	118	28	291	7	762	31	.2084	54	38
23	146	29	284	6	793	30	.2030	54	37
24	175	28	278	7	823	31	.1976	54	36
25	.23203	28	.97271	7	.23854	31	4.1922	54	**35**
26	231	29	264	7	885	31	.1868	54	34
27	260	28	257	6	916	30	.1814	54	33
28	288	28	251	7	946	31	.1760	54	32
29	316	29	244	7	977	31	.1706	53	31
30	.23345	28	.97237	7	.24008	31	4.1653	53	**30**
31	373	28	230	7	039	30	.1600	53	29
32	401	28	223	6	069	31	.1547	54	28
33	429	29	217	7	100	31	.1493	52	27
34	458	28	210	7	131	31	.1441	53	26
35	.23486	28	.97203	7	.24162	31	4.1388	53	**25**
36	514	28	196	7	193	30	.1335	53	24
37	542	29	189	7	223	31	.1282	52	23
38	571	28	182	6	254	31	.1230	52	22
39	599	28	176	7	285	31	.1178	52	21
40	.23627	29	.97169	7	.24316	31	4.1126	52	**20**
41	656	28	162	7	347	30	.1074	52	19
42	684	28	155	7	377	31	.1022	52	18
43	712	28	148	7	408	31	.0970	52	17
44	740	29	141	7	439	31	.0918	51	16
45	.23769	28	.97134	7	.24470	31	4.0867	52	**15**
46	797	28	127	7	501	31	.0815	51	14
47	825	28	120	7	532	30	.0764	51	13
48	853	29	113	7	562	31	.0713	51	12
49	882	28	106	6	593	31	.0662	51	11
50	.23910	28	.97100	7	.24624	31	4.0611	51	**10**
51	938	28	093	7	655	31	.0560	51	9
52	966	29	086	7	686	31	.0509	50	8
53	995	28	079	7	717	30	.0459	51	7
54	.24023	28	072	7	747	31	.0408	50	6
55	.24051	28	.97065	7	.24778	31	4.0358	50	**5**
56	079	29	058	7	809	31	.0308	51	4
57	108	28	051	7	840	31	.0257	50	3
58	136	28	044	7	871	31	.0207	49	2
59	164	28	037	7	902	31	.0158	50	1
60	.24192		.97030		.24933		4.0108		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

76°

P. P.

	32	31
1	0.5	0.5
2	1.1	1.0
3	1.6	1.6
4	2.1	2.1
5	2.7	2.6
6	3.2	3.1
7	3.7	3.6
8	4.3	4.1
9	4.8	4.6
10	5.3	5.2
20	10.7	10.3
30	16.0	15.5
40	21.3	20.7
50	26.7	25.8

	30	29
1	0.5	0.5
2	1.0	1.0
3	1.5	1.4
4	2.0	1.9
5	2.5	2.4
6	3.0	2.9
7	3.5	3.4
8	4.0	3.9
9	4.5	4.4
10	5.0	4.8
20	10.0	9.7
30	15.0	14.5
40	20.0	19.3
50	25.0	24.2

P. P.

14°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.24192	28	.97030	7	.24933	31	4.0108	50	**60**
1	220	29	023	8	964	31	.0058	49	59
2	249	28	015	7	995	31	.0009	50	58
3	277	28	008	7	.25026	30	3.9959	49	57
4	305	28	001	7	056	31	.9910	49	56
5	.24333	29	.96994	7	.25087	31	3.9861	49	**55**
6	362	28	987	7	118	31	.9812	49	54
7	390	28	980	7	149	31	.9763	49	53
8	418	28	973	7	180	31	.9714	49	52
9	446	28	966	7	211	31	.9665	48	51
10	.24474	29	.96959	7	.25242	31	3.9617	49	**50**
11	503	28	952	7	273	31	.9568	48	49
12	531	28	945	8	304	31	.9520	49	48
13	559	28	937	7	335	31	.9471	48	47
14	587	28	930	7	366	31	.9423	48	46
15	.24615	29	.96923	7	.25397	31	3.9375	48	**45**
16	644	28	916	7	428	31	.9327	48	44
17	672	28	909	7	459	31	.9279	47	43
18	700	28	902	8	490	31	.9232	48	42
19	728	28	894	7	521	31	.9184	48	41
20	.24756	28	.96887	7	.25552	31	3.9136	47	**40**
21	784	29	880	7	583	31	.9089	47	39
22	813	28	873	7	614	31	.9042	47	38
23	841	28	866	8	645	31	.8995	48	37
24	869	28	858	7	676	31	.8947	47	36
25	.24897	28	.96851	7	.25707	31	3.8900	46	**35**
26	925	29	844	7	738	31	.8854	47	34
27	954	28	837	8	769	31	.8807	47	33
28	982	28	829	7	800	31	.8760	46	32
29	.25010	28	822	7	831	31	.8714	47	31
30	.25038	28	.96815	8	.25862	31	3.8667	46	**30**
31	066	28	807	7	893	31	.8621	46	29
32	094	28	800	7	924	31	.8575	47	28
33	122	29	793	7	955	31	.8528	46	27
34	151	28	786	8	986	31	.8482	46	26
35	.25179	28	.96778	7	.26017	31	3.8436	45	**25**
36	207	28	771	7	048	31	.8391	46	24
37	235	28	764	8	079	31	.8345	46	23
38	263	28	756	7	110	31	.8299	45	22
39	291	29	749	7	141	31	.8254	46	21
40	.25320	28	.96742	8	.26172	31	3.8208	45	**20**
41	348	28	734	7	203	32	.8163	45	19
42	376	28	727	8	235	31	.8118	45	18
43	404	28	719	7	266	31	.8073	45	17
44	432	28	712	7	297	31	.8028	45	16
45	.25460	28	.96705	8	.26328	31	3.7983	45	**15**
46	488	28	697	7	359	31	.7938	45	14
47	516	29	690	8	390	31	.7893	45	13
48	545	28	682	7	421	31	.7848	44	12
49	573	28	675	8	452	31	.7804	44	11
50	.25601	28	.96667	7	.26483	32	3.7760	45	**10**
51	629	28	660	7	515	31	.7715	44	9
52	657	28	653	8	546	31	.7671	44	8
53	685	28	645	7	577	31	.7627	44	7
54	713	28	638	8	608	31	.7583	44	6
55	.25741	28	.96630	7	.26639	31	3.7539	44	**5**
56	769	29	623	8	670	31	.7495	44	4
57	798	28	615	7	701	32	.7451	43	3
58	826	28	608	8	733	31	.7408	44	2
59	854	28	600	7	764	31	.7364	43	1
60	.25882		.96593		.26795		3.7321		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

75°

P. P.

	28	8
1	0.5	0.1
2	0.9	0.3
3	1.4	0.4
4	1.9	0.5
5	2.3	0.7
6	2.8	0.8
7	3.3	0.9
8	3.7	1.1
9	4.2	1.2
10	4.7	1.3
20	9.3	2.7
30	14.0	4.0
40	18.7	5.3
50	23.3	6.7

	7	6
1	0.1	0.1
2	0.2	0.2
3	0.4	0.3
4	0.5	0.4
5	0.6	0.5
6	0.7	0.6
7	0.8	0.7
8	0.9	0.8
9	1.0	0.9
10	1.2	1.0
20	2.3	2.0
30	3.5	3.0
40	4.7	4.0
50	5.8	5.0

15°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.25882	28	.96593	8	.26795	31	3.7321	44	**60**
1	910	28	585	7	826	31	.7277	43	59
2	938	28	578	8	857	31	.7234	43	58
3	966	28	570	8	888	32	.7191	43	57
4	994	28	562	7	920	31	.7148	43	56
5	.26022	28	.96555	8	.26951	31	3.7105	43	**55**
6	050	29	547	7	982	31	.7062	43	54
7	079	28	540	8	.27013	31	.7019	43	53
8	107	28	532	8	044	32	.6976	43	52
9	135	28	524	7	076	31	.6933	42	51
10	.26163	28	.96517	8	.27107	31	3.6891	43	**50**
11	191	28	509	7	138	31	.6848	42	49
12	219	28	502	8	169	32	.6806	42	48
13	247	28	494	8	201	31	.6764	42	47
14	275	28	486	7	232	31	.6722	42	46
15	.26303	28	.96479	8	.27263	31	3.6680	42	**45**
16	331	28	471	8	294	32	.6638	42	44
17	359	28	463	7	326	31	.6596	42	43
18	387	28	456	8	357	31	.6554	42	42
19	415	28	448	8	388	31	.6512	42	41
20	.26443	28	.96440	7	.27419	32	3.6470	41	**40**
21	471	29	433	8	451	31	.6429	42	39
22	500	28	425	8	482	31	.6387	41	38
23	528	28	417	7	513	32	.6346	41	37
24	556	28	410	8	545	31	.6305	41	36
25	.26584	28	.96402	8	.27576	31	3.6264	42	**35**
26	612	28	394	8	607	31	.6222	41	34
27	640	28	386	7	638	32	.6181	41	33
28	668	28	379	8	670	31	.6140	40	32
29	696	28	371	8	701	31	.6100	41	31
30	.26724	28	.96363	8	.27732	32	3.6059	41	**30**
31	752	28	355	8	764	31	.6018	40	29
32	780	28	347	7	795	31	.5978	41	28
33	808	28	340	8	826	32	.5937	40	27
34	836	28	332	8	858	31	.5897	41	26
35	.26864	28	.96324	8	.27889	32	3.5856	40	**25**
36	892	28	316	8	921	31	.5816	40	24
37	920	28	308	7	952	31	.5776	40	23
38	948	28	301	8	983	32	.5736	40	22
39	976	28	293	8	.28015	31	.5696	40	21
40	.27004	28	.96285	8	.28046	31	3.5656	40	**20**
41	032	28	277	8	077	32	.5616	40	19
42	060	28	269	8	109	31	.5576	40	18
43	088	28	261	8	140	32	.5536	39	17
44	116	28	253	7	172	31	.5497	40	16
45	.27144	28	.96246	8	.28203	31	3.5457	39	**15**
46	172	28	238	8	234	32	.5418	39	14
47	200	28	230	8	266	31	.5379	40	13
48	228	28	222	8	297	32	.5339	39	12
49	256	28	214	8	329	31	.5300	39	11
50	.27284	28	.96206	8	.28360	31	3.5261	39	**10**
51	312	28	198	8	391	32	.5222	39	9
52	340	28	190	8	423	31	.5183	39	8
53	368	28	182	8	454	32	.5144	39	7
54	396	28	174	8	486	31	.5105	38	6
55	.27424	28	.96166	8	.28517	32	3.5067	39	**5**
56	452	28	158	8	549	31	.5028	39	4
57	480	28	150	8	580	32	.4989	38	3
58	508	28	142	8	612	31	.4951	39	2
59	536	28	134	8	643	32	.4912	38	1
60	.27564		.96126		.28675		3.4874		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

74°

P. P.

	32	31
1	0.5	0.5
2	1.1	1.0
3	1.6	1.6
4	2.1	2.1
5	2.7	2.6
6	3.2	3.1
7	3.7	3.6
8	4.3	4.1
9	4.8	4.6
10	5.3	5.2
20	10.7	10.3
30	16.0	15.5
40	21.3	20.7
50	26.7	25.8

	29	28
1	0.5	0.5
2	1.0	0.9
3	1.4	1.4
4	1.9	1.9
5	2.4	2.3
6	2.9	2.8
7	3.4	3.3
8	3.9	3.7
9	4.4	4.2
10	4.8	4.7
20	9.7	9.3
30	14.5	14.0
40	19.3	18.7
50	24.2	23.3

P. P.

16°

P. P.

	27	9
1	0.4	0.2
2	0.9	0.3
3	1.4	0.4
4	1.8	0.6
5	2.2	0.8
6	2.7	0.9
7	3.2	1.0
8	3.6	1.2
9	4.0	1.4
10	4.5	1.5
20	9.0	3.0
30	13.5	4.5
40	18.0	6.0
50	22.5	7.5

	8	7
1	0.1	0.1
2	0.3	0.2
3	0.4	0.4
4	0.5	0.5
5	0.7	0.6
6	0.8	0.7
7	0.9	0.8
8	1.1	0.9
9	1.2	1.0
10	1.3	1.2
20	2.7	2.3
30	4.0	3.5
40	5.3	4.7
50	6.7	5.8

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.27564	28	.96126	8	.28675	31	3.4874	38	**60**
1	592	28	118	8	706	32	.4836	38	59
2	620	28	110	8	738	31	.4798	38	58
3	648	28	102	8	769	32	.4760	38	57
4	676	28	094	8	801	31	.4722	38	56
5	.27704	27	.96086	8	.28832	32	3.4684	38	**55**
6	731	28	078	8	864	31	.4646	38	54
7	759	28	070	8	895	32	.4608	38	53
8	787	28	062	8	927	31	.4570	37	52
9	815	28	054	8	958	32	.4533	38	51
10	.27843	28	.96046	9	.28990	31	3.4495	37	**50**
11	871	28	037	8	.29021	32	.4458	38	49
12	899	28	029	8	053	31	.4420	37	48
13	927	28	021	8	084	32	.4383	37	47
14	955	28	013	8	116	31	.4346	38	46
15	.27983	28	.96005	8	.29147	32	3.4308	37	**45**
16	.28011	28	.95997	8	179	31	.4271	37	44
17	039	28	989	8	210	32	.4234	37	43
18	067	28	981	9	242	32	.4197	37	42
19	095	28	972	8	274	31	.4160	36	41
20	.28123	27	.95964	8	.29305	32	3.4124	37	**40**
21	150	28	956	8	337	31	.4087	37	39
22	178	28	948	8	368	32	.4050	36	38
23	206	28	940	9	400	32	.4014	37	37
24	234	28	931	8	432	31	.3977	36	36
25	.28262	28	.95923	8	.29463	32	3.3941	37	**35**
26	290	28	915	8	495	31	.3904	36	34
27	318	28	907	9	526	32	.3868	36	33
28	346	28	898	8	558	32	.3832	36	32
29	374	28	890	8	590	31	.3796	37	31
30	.28402	27	.95882	8	.29621	32	3.3759	36	**30**
31	429	28	874	9	653	32	.3723	36	29
32	457	28	865	8	685	31	.3687	35	28
33	485	28	857	8	716	32	.3652	36	27
34	513	28	849	8	748	32	.3616	36	26
35	.28541	28	.95841	9	.29780	31	3.3580	36	**25**
36	569	28	832	8	811	32	.3544	35	24
37	597	28	824	8	843	32	.3509	36	23
38	625	27	816	9	875	31	.3473	35	22
39	652	28	807	8	906	32	.3438	36	21
40	.28680	28	.95799	8	.29938	32	3.3402	35	**20**
41	708	28	791	9	970	31	.3367	35	19
42	736	28	782	8	.30001	32	.3332	35	18
43	764	28	774	8	033	32	.3297	36	17
44	792	28	766	9	065	32	.3261	35	16
45	.28820	27	.95757	8	.30097	31	3.3226	35	**15**
46	847	28	749	9	128	32	.3191	35	14
47	875	28	740	8	160	32	.3156	34	13
48	903	28	732	8	192	32	.3122	35	12
49	931	28	724	9	224	31	.3087	35	11
50	.28959	28	.95715	8	.30255	32	3.3052	35	**10**
51	987	28	707	9	287	32	.3017	34	9
52	.29015	27	698	8	319	32	.2983	35	8
53	042	28	690	9	351	31	.2948	34	7
54	070	28	681	8	382	32	.2914	35	6
55	.29098	28	.95673	9	.30414	32	3.2879	34	**5**
56	126	28	664	8	446	32	.2845	34	4
57	154	28	656	9	478	31	.2811	34	3
58	182	27	647	8	509	32	.2777	34	2
59	209	28	639	9	541	32	.2743	34	1
60	.29237		.95630		.30573		3.2709		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

P. P.

73°

17°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	′
0	.29237	28	.95630	8	.30573	32	3.2709	34	**60**
1	265	28	622	9	605	32	.2675	34	59
2	293	28	613	8	637	32	.2641	34	58
3	321	27	605	9	669	31	.2607	34	57
4	348	28	596	8	700	32	.2573	34	56
5	.29376	28	.95588	9	.30732	32	3.2539	33	**55**
6	404	28	579	8	764	32	.2506	34	54
7	432	28	571	9	796	32	.2472	34	53
8	460	27	562	8	828	32	.2438	33	52
9	487	28	554	9	860	31	.2405	34	51
10	.29515	28	.95545	9	.30891	32	3.2371	33	**50**
11	543	28	536	8	923	32	.2338	33	49
12	571	28	528	9	955	32	.2305	33	48
13	599	27	519	8	987	32	.2272	34	47
14	626	28	511	9	.31019	32	.2238	33	46
15	.29654	28	.95502	9	.31051	32	3.2205	33	**45**
16	682	28	493	8	083	32	.2172	33	44
17	710	27	485	9	115	32	.2139	33	43
18	737	28	476	9	147	31	.2106	33	42
19	765	28	467	8	178	32	.2073	32	41
20	.29793	28	.95459	9	.31210	32	3.2041	33	**40**
21	821	28	450	9	242	32	.2008	33	39
22	849	27	441	8	274	32	.1975	32	38
23	876	28	433	9	306	32	.1943	33	37
24	904	28	424	9	338	32	.1910	32	36
25	.29932	28	.95415	8	.31370	32	3.1878	33	**35**
26	960	27	407	9	402	32	.1845	32	34
27	987	28	398	9	434	32	.1813	33	33
28	.30015	28	389	9	466	32	.1780	32	32
29	043	28	380	8	498	32	.1748	32	31
30	.30071	27	.95372	9	.31530	32	3.1716	32	**30**
31	098	28	363	9	562	32	.1684	32	29
32	126	28	354	9	594	32	.1652	32	28
33	154	28	345	8	626	32	.1620	32	27
34	182	27	337	9	658	32	.1588	32	26
35	.30209	28	.95328	9	.31690	32	3.1556	32	**25**
36	237	28	319	9	722	32	.1524	32	24
37	265	27	310	9	754	32	.1492	32	23
38	292	28	301	8	786	32	.1460	31	22
39	320	28	293	9	818	32	.1429	32	21
40	.30348	28	.95284	9	.31850	32	3.1397	31	**20**
41	376	27	275	9	882	32	.1366	32	19
42	403	28	266	9	914	32	.1334	31	18
43	431	28	257	9	946	32	.1303	32	17
44	459	27	248	8	978	32	.1271	31	16
45	.30486	28	.95240	9	.32010	32	3.1240	31	**15**
46	514	28	231	9	042	32	.1209	31	14
47	542	28	222	9	074	32	.1178	32	13
48	570	27	213	9	106	33	.1146	31	12
49	597	28	204	9	139	32	.1115	31	11
50	.30625	28	.95195	9	.32171	32	3.1084	31	**10**
51	653	27	186	9	203	32	.1053	31	9
52	680	28	177	9	235	32	.1022	31	8
53	708	28	168	9	267	32	.0991	30	7
54	736	27	159	9	299	32	.0961	31	6
55	.30763	28	.95150	8	.32331	32	3.0930	31	**5**
56	791	28	142	9	363	33	.0899	31	4
57	819	27	133	9	396	32	.0868	30	3
58	846	28	124	9	428	32	.0838	31	2
59	874	28	115	9	460	32	.0807	30	1
60	.30902		.95106		.32492		3.0777		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

72°

P. P.

	34	33
1	0.6	0.6
2	1.1	1.1
3	1.7	1.6
4	2.3	2.2
5	2.8	2.8
6	3.4	3.3
7	4.0	3.8
8	4.5	4.4
9	5.1	5.0
10	5.7	5.5
20	11.3	11.0
30	17.0	16.5
40	22.7	22.0
50	28.3	27.5

	32	31
1	0.5	0.5
2	1.1	1.0
3	1.6	1.6
4	2.1	2.1
5	2.7	2.6
6	3.2	3.1
7	3.7	3.6
8	4.3	4.1
9	4.8	4.6
10	5.3	5.2
20	10.7	10.3
30	16.0	15.5
40	21.3	20.7
50	26.7	25.8

	30	29
1	0.5	0.5
2	1.0	1.0
3	1.5	1.4
4	2.0	1.9
5	2.5	2.4
6	3.0	2.9
7	3.5	3.4
8	4.0	3.9
9	4.5	4.4
10	5.0	4.8
20	10.0	9.7
30	15.0	14.5
40	20.0	19.3
50	25.0	24.2

P. P.

18°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	′
0	.30902	27	.95106	9	.32492	32	3.0777	31	**60**
1	929	28	097	9	524	32	.0746	30	59
2	957	28	088	9	556	32	.0716	30	58
3	985	27	079	9	588	33	.0686	31	57
4	.31012	28	070	9	621	32	.0655	30	56
5	.31040	28	.95061	9	.32653	32	3.0625	30	**55**
6	068	27	052	9	685	32	.0595	30	54
7	095	28	043	10	717	32	.0565	30	53
8	123	28	033	9	749	33	.0535	30	52
9	151	27	024	9	782	32	.0505	30	51
10	.31178	28	.95015	9	.32814	32	3.0475	30	**50**
11	206	27	006	9	846	32	.0445	30	49
12	233	28	.94997	9	878	33	.0415	30	48
13	261	28	988	9	911	32	.0385	29	47
14	289	27	979	9	943	32	.0356	30	46
15	.31316	28	.94970	9	.32975	32	3.0326	30	**45**
16	344	28	961	9	.33007	33	.0296	29	44
17	372	27	952	9	040	32	.0267	30	43
18	399	28	943	10	072	32	.0237	29	42
19	427	27	933	9	104	32	.0208	30	41
20	.31454	28	.94924	9	.33136	33	3.0178	29	**40**
21	482	28	915	9	169	32	.0149	29	39
22	510	27	906	9	201	32	.0120	30	38
23	537	28	897	9	233	33	.0090	29	37
24	565	28	888	10	266	32	.0061	29	36
25	.31593	27	.94878	9	.33298	32	3.0032	29	**35**
26	620	28	869	9	330	33	.0003	29	34
27	648	27	860	9	363	32	2.9974	29	33
28	675	28	851	9	395	32	.9945	29	32
29	703	27	842	10	427	33	.9916	29	31
30	.31730	28	.94832	9	.33460	32	2.9887	29	**30**
31	758	28	823	9	492	32	.9858	29	29
32	786	27	814	9	524	33	.9829	29	28
33	813	28	805	10	557	32	.9800	28	27
34	841	27	795	9	589	32	.9772	29	26
35	.31868	28	.94786	9	.33621	33	2.9743	29	**25**
36	896	27	777	9	654	32	.9714	28	24
37	923	28	768	10	686	32	.9686	29	23
38	951	28	758	9	718	33	.9657	28	22
39	979	27	749	9	751	32	.9629	29	21
40	.32006	28	.94740	10	.33783	33	2.9600	28	**20**
41	034	27	730	9	816	32	.9572	28	19
42	061	28	721	9	848	33	.9544	29	18
43	089	27	712	10	881	32	.9515	28	17
44	116	28	702	9	913	32	.9487	28	16
45	.32144	27	.94693	9	.33945	33	2.9459	28	**15**
46	171	28	684	10	978	32	.9431	28	14
47	199	28	674	9	.34010	33	.9403	28	13
48	227	27	665	9	043	32	.9375	28	12
49	254	28	656	10	075	33	.9347	28	11
50	.32282	27	.94646	9	.34108	32	2.9319	28	**10**
51	309	28	637	10	140	33	.9291	28	9
52	337	27	627	9	173	32	.9263	28	8
53	364	28	618	9	205	33	.9235	27	7
54	392	27	609	10	238	32	.9208	28	6
55	.32419	28	.94599	9	.34270	33	2.9180	28	**5**
56	447	27	590	10	303	32	.9152	27	4
57	474	28	580	9	335	33	.9125	28	3
58	502	27	571	10	368	32	.9097	27	2
59	529	28	561	9	400	33	.9070	28	1
60	.32557		.94552		.34433		2.9042		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

71°

P. P.

	28	27
1	0.5	0.4
2	0.9	0.9
3	1.4	1.4
4	1.9	1.8
5	2.3	2.2
6	2.8	2.7
7	3.3	3.2
8	3.7	3.6
9	4.2	4.0
10	4.7	4.5
20	9.3	9.0
30	14.0	13.5
40	18.7	18.0
50	23.3	22.5

	10	9
1	0.2	0.2
2	0.3	0.3
3	0.5	0.4
4	0.7	0.6
5	0.8	0.8
6	1.0	0.9
7	1.2	1.0
8	1.3	1.2
9	1.5	1.4
10	1.7	1.5
20	3.3	3.0
30	5.0	4.5
40	6.7	6.0
50	8.3	7.5

	8
1	0.1
2	0.3
3	0.4
4	0.5
5	0.7
6	0.8
7	0.9
8	1.1
9	1.2
10	1.3
20	2.7
30	4.0
40	5.3
50	6.7

P. P.

19°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	′
0	.32557	27	.94552	10	.34433	32	2.9042	27	**60**
1	584	28	542	9	465	33	.9015	28	59
2	612	27	533	10	498	32	.8987	27	58
3	639	28	523	9	530	33	.8960	27	57
4	667	27	514	10	563	33	.8933	28	56
5	.32694	28	.94504	9	.34596	32	2.8905	27	**55**
6	722	27	495	10	628	33	.8878	27	54
7	749	28	485	9	661	32	.8851	27	53
8	777	27	476	10	693	33	.8824	27	52
9	804	28	466	9	726	32	.8797	27	51
10	.32832	27	.94457	10	.34758	33	2.8770	27	**50**
11	859	28	447	9	791	33	.8743	27	49
12	887	27	438	10	824	32	.8716	27	48
13	914	28	428	10	856	33	.8689	27	47
14	942	27	418	9	889	33	.8662	26	46
15	.32969	28	.94409	10	.34922	32	2.8636	27	**45**
16	997	27	399	9	954	33	.8609	27	44
17	.33024	27	390	10	987	33	.8582	26	43
18	051	28	380	10	.35020	32	.8556	27	42
19	079	27	370	9	052	33	.8529	27	41
20	.33106	28	.94361	10	.35085	33	2.8502	26	**40**
21	134	27	351	9	118	32	.8476	27	39
22	161	28	342	10	150	33	.8449	26	38
23	189	27	332	10	183	33	.8423	26	37
24	216	28	322	9	216	32	.8397	27	36
25	.33244	27	.94313	10	.35248	33	2.8370	26	**35**
26	271	27	303	10	281	33	.8344	26	34
27	298	28	293	9	314	32	.8318	27	33
28	326	27	284	10	346	33	.8291	26	32
29	353	28	274	10	379	33	.8265	26	31
30	.33381	27	.94264	10	.35412	33	2.8239	26	**30**
31	408	28	254	9	445	32	.8213	26	29
32	436	27	245	10	477	33	.8187	26	28
33	463	27	235	10	510	33	.8161	26	27
34	490	28	225	10	543	33	.8135	26	26
35	.33518	27	.94215	9	.35576	32	2.8109	26	**25**
36	545	28	206	10	608	33	.8083	26	24
37	573	27	196	10	641	33	.8057	25	23
38	600	27	186	10	674	33	.8032	26	22
39	627	28	176	9	707	33	.8006	26	21
40	.33655	27	.94167	10	.35740	32	2.7980	25	**20**
41	682	28	157	10	772	33	.7955	26	19
42	710	27	147	10	805	33	.7929	26	18
43	737	27	137	10	838	33	.7903	25	17
44	764	28	127	9	871	33	.7878	26	16
45	.33792	27	.94118	10	.35904	33	2.7852	25	**15**
46	819	27	108	10	937	32	.7827	26	14
47	846	28	098	10	969	33	.7801	25	13
48	874	27	088	10	.36002	33	.7776	25	12
49	901	28	078	10	035	33	.7751	26	11
50	.33929	27	.94068	10	.36068	33	2.7725	25	**10**
51	956	27	058	9	101	33	.7700	25	9
52	983	28	049	10	134	33	.7675	25	8
53	.34011	27	039	10	167	32	.7650	25	7
54	038	27	029	10	199	33	.7625	25	6
55	.34065	28	.94019	10	.36232	33	2.7600	25	**5**
56	093	27	009	10	265	33	.7575	25	4
57	120	27	.93999	10	298	33	.7550	25	3
58	147	28	989	10	331	33	.7525	25	2
59	175	27	979	10	364	33	.7500	25	1
60	.34202		.93969		.36397		2.7475		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

70°

P. P.

	34	33
1	0.6	0.6
2	1.1	1.1
3	1.7	1.6
4	2.3	2.2
5	2.8	2.8
6	3.4	3.3
7	4.0	3.8
8	4.5	4.4
9	5.1	5.0
10	5.7	5.5
20	11.3	11.0
30	17.0	16.5
40	22.7	22.0
50	28.3	27.5

	32	28
1	0.5	0.5
2	1.1	0.9
3	1.6	1.4
4	2.1	1.9
5	2.7	2.3
6	3.2	2.8
7	3.7	3.3
8	4.3	3.7
9	4.8	4.2
10	5.3	4.7
20	10.7	9.3
30	16.0	14.0
40	21.3	18.7
50	26.7	23.3

	27	26
1	0.4	0.4
2	0.9	0.9
3	1.4	1.3
4	1.8	1.7
5	2.2	2.2
6	2.7	2.6
7	3.2	3.0
8	3.6	3.5
9	4.0	3.9
10	4.5	4.3
20	9.0	8.7
30	13.5	13.0
40	18.0	17.3
50	22.5	21.7

	25	24
1	0.4	0.4
2	0.8	0.8
3	1.2	1.2
4	1.7	1.6
5	2.1	2.0
6	2.5	2.4
7	2.9	2.8
8	3.3	3.2
9	3.8	3.6
10	4.2	4.0
20	8.3	8.0
30	12.5	12.0
40	16.7	16.0
50	20.8	20.0

P. P.

20°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.34202	27	.93969	10	.36397	33	2.7475	25	**60**
1	229	28	959	10	430	33	.7450	25	59
2	257	27	949	10	463	33	.7425	25	58
3	284	27	939	10	496	33	.7400	24	57
4	311	28	929	10	529	33	.7376	25	56
5	.34339	27	.93919	10	.36562	33	2.7351	25	**55**
6	366	27	909	10	595	33	.7326	24	54
7	393	28	899	10	628	33	.7302	25	53
8	421	27	889	10	661	33	.7277	24	52
9	448	27	879	10	694	33	.7253	25	51
10	.34475	28	.93869	10	.36727	33	2.7228	24	**50**
11	503	27	859	10	760	33	.7204	25	49
12	530	27	849	10	793	33	.7179	24	48
13	557	27	839	10	826	33	.7155	25	47
14	584	28	829	10	859	33	.7130	24	46
15	.34612	27	.93819	10	.36892	33	2.7106	24	**45**
16	639	27	809	10	925	33	.7082	24	44
17	666	28	799	10	958	33	.7058	24	43
18	694	27	789	10	991	33	.7034	25	42
19	721	27	779	10	.37024	33	.7009	24	41
20	.34748	27	.93769	10	.37057	33	2.6985	24	**40**
21	775	28	759	11	090	33	.6961	24	39
22	803	27	748	10	123	34	.6937	24	38
23	830	27	738	10	157	33	.6913	24	37
24	857	27	728	10	190	33	.6889	24	36
25	.34884	28	.93718	10	.37223	33	2.6865	24	**35**
26	912	27	708	10	256	33	.6841	23	34
27	939	27	698	10	289	33	.6818	24	33
28	966	27	688	11	322	33	.6794	24	32
29	993	28	677	10	355	33	.6770	24	31
30	.35021	27	.93667	10	.37388	34	2.6746	23	**30**
31	048	27	657	10	422	33	.6723	24	29
32	075	27	647	10	455	33	.6699	24	28
33	102	28	637	11	488	33	.6675	23	27
34	130	27	626	10	521	33	.6652	24	26
35	.35157	27	.93616	10	.37554	34	2.6628	23	**25**
36	184	27	606	10	588	33	.6605	24	24
37	211	28	596	11	621	33	.6581	23	23
38	239	27	585	10	654	33	.6558	24	22
39	266	27	575	10	687	33	.6534	23	21
40	.35293	27	.93565	10	.37720	34	2.6511	23	**20**
41	320	27	555	11	754	33	.6488	24	19
42	347	28	544	10	787	33	.6464	23	18
43	375	27	534	10	820	33	.6441	23	17
44	402	27	524	10	853	34	.6418	23	16
45	.35429	27	.93514	11	.37887	33	2.6395	24	**15**
46	456	28	503	10	920	33	.6371	23	14
47	484	27	493	10	953	33	.6348	23	13
48	511	27	483	11	986	34	.6325	23	12
49	538	27	472	10	.38020	33	.6302	23	11
50	.35565	27	.93462	10	.38053	33	2.6279	23	**10**
51	592	27	452	11	086	34	.6256	23	9
52	619	28	441	10	120	33	.6233	23	8
53	647	27	431	11	153	33	.6210	23	7
54	674	27	420	10	186	34	.6187	22	6
55	.35701	27	.93410	10	.38220	33	2.6165	23	**5**
56	728	27	400	11	253	33	.6142	23	4
57	755	27	389	10	286	34	.6119	23	3
58	782	28	379	11	320	33	.6096	22	2
59	810	27	368	10	353	33	.6074	23	1
60	.35837		.93358		.38386		2.6051		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

69°

P. P.

	23	22
1	0.4	0.4
2	0.8	0.7
3	1.2	1.1
4	1.5	1.5
5	1.9	1.8
6	2.3	2.2
7	2.7	2.6
8	3.1	2.9
9	3.4	3.3
10	3.8	3.7
20	7.7	7.3
30	11.5	11.0
40	15.3	14.7
50	19.2	18.3

	10	11
1	0.2	0.2
2	0.3	0.4
3	0.5	0.6
4	0.7	0.7
5	0.8	0.9
6	1.0	1.1
7	1.2	1.3
8	1.3	1.5
9	1.5	1.6
10	1.7	1.8
20	3.3	3.7
30	5.0	5.5
40	6.7	7.3
50	8.3	9.2

	9
1	0.2
2	0.3
3	0.4
4	0.6
5	0.8
6	0.9
7	1.0
8	1.2
9	1.4
10	1.5
20	3.0
30	4.5
40	6.0
50	7.5

P. P.

21°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.35837	27	.93358	10	.38386	34	2.6051	23	**60**
1	864	27	348	11	420	33	.6028	22	59
2	891	27	337	10	453	34	.6006	23	58
3	918	27	327	11	487	33	.5983	22	57
4	945	28	316	10	520	33	.5961	23	56
5	.35973	27	.93306	11	.38553	34	2.5938	22	**55**
6	.36000	27	295	10	587	33	.5916	23	54
7	027	27	285	11	620	34	.5893	22	53
8	054	27	274	10	654	33	.5871	23	52
9	081	27	264	11	687	34	.5848	22	51
10	.36108	27	.93253	10	.38721	33	2.5826	22	**50**
11	135	27	243	11	754	33	.5804	22	49
12	162	28	232	10	787	34	.5782	23	48
13	190	27	222	11	821	33	.5759	22	47
14	217	27	211	10	854	34	.5737	22	46
15	.36244	27	.93201	11	.38888	33	2.5715	22	**45**
16	271	27	190	10	921	34	.5693	22	44
17	298	27	180	11	955	33	.5671	22	43
18	325	27	169	10	988	34	.5649	22	42
19	352	27	159	11	.39022	33	.5627	22	41
20	.36379	27	.93148	11	.39055	34	2.5605	22	**40**
21	406	28	137	10	089	33	.5583	22	39
22	434	27	127	11	122	34	.5561	22	38
23	461	27	116	10	156	34	.5539	22	37
24	488	27	106	11	190	33	.5517	22	36
25	.36515	27	.93095	11	.39223	34	2.5495	22	**35**
26	542	27	084	10	257	33	.5473	21	34
27	569	27	074	11	290	34	.5452	22	33
28	596	27	063	11	324	33	.5430	22	32
29	623	27	052	10	357	34	.5408	22	31
30	.36650	27	.93042	11	.39391	34	2.5386	21	**30**
31	677	27	031	11	425	33	.5365	22	29
32	704	27	020	10	458	34	.5343	21	28
33	731	27	010	11	492	34	.5322	22	27
34	758	27	.92999	11	526	33	.5300	21	26
35	.36785	27	.92988	10	.39559	34	2.5279	22	**25**
36	812	27	978	11	593	33	.5257	21	24
37	839	28	967	11	626	34	.5236	22	23
38	867	27	956	11	660	34	.5214	21	22
39	894	27	945	10	694	33	.5193	21	21
40	.36921	27	.92935	11	.39727	34	2.5172	22	**20**
41	948	27	924	11	761	34	.5150	21	19
42	975	27	913	11	795	34	.5129	21	18
43	.37002	27	902	10	829	33	.5108	22	17
44	029	27	892	11	862	34	.5086	21	16
45	.37056	27	.92881	11	.39896	34	2.5065	21	**15**
46	083	27	870	11	930	33	.5044	21	14
47	110	27	859	10	963	34	.5023	21	13
48	137	27	849	11	997	34	.5002	21	12
49	164	27	838	11	.40031	34	.4981	21	11
50	.37191	27	.92827	11	.40065	33	2.4960	21	**10**
51	218	27	816	11	098	34	.4939	21	9
52	245	27	805	11	132	34	.4918	21	8
53	272	27	794	10	166	34	.4897	21	7
54	299	27	784	11	200	34	.4876	21	6
55	.37326	27	.92773	11	.40234	33	2.4855	21	**5**
56	353	27	762	11	267	34	.4834	21	4
57	380	27	751	11	301	34	.4813	21	3
58	407	27	740	11	335	34	.4792	20	2
59	434	27	729	11	369	34	.4772	21	1
60	.37461		.92718		.40403		2.4751		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

68°

P. P.

	35	34
1	0.6	0.6
2	1.2	1.1
3	1.8	1.7
4	2.3	2.3
5	2.9	2.8
6	3.5	3.4
7	4.1	4.0
8	4.7	4.5
9	5.2	5.1
10	5.8	5.7
20	11.7	11.3
30	17.5	17.0
40	23.3	22.7
50	29.2	28.3

	33	28
1	0.6	0.5
2	1.1	0.9
3	1.6	1.4
4	2.2	1.9
5	2.8	2.3
6	3.3	2.8
7	3.8	3.3
8	4.4	3.7
9	5.0	4.2
10	5.5	4.7
20	11.0	9.3
30	16.5	14.0
40	22.0	18.7
50	27.5	23.3

	27	26
1	0.4	0.4
2	0.9	0.9
3	1.4	1.3
4	1.8	1.7
5	2.2	2.2
6	2.7	2.6
7	3.2	3.0
8	3.6	3.5
9	4.0	3.9
10	4.5	4.3
20	9.0	8.7
30	13.5	13.0
40	18.0	17.3
50	22.5	21.7

	23	22
1	0.4	0.4
2	0.8	0.7
3	1.2	1.1
4	1.5	1.5
5	1.9	1.8
6	2.3	2.2
7	2.7	2.6
8	3.1	2.9
9	3.4	3.3
10	3.8	3.7
20	7.7	7.3
30	11.5	11.0
40	15.3	14.7
50	19.2	18.3

P. P.

22°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.37461	27	.92718	11	.40403	33	2.4751	21	**60**
1	488	27	707	10	436	34	.4730	21	59
2	515	27	697	11	470	34	.4709	20	58
3	542	27	686	11	504	34	.4689	21	57
4	569	26	675	11	538	34	.4668	20	56
5	.37595	27	.92664	11	.40572	34	2.4648	21	**55**
6	622	27	653	11	606	34	.4627	21	54
7	649	27	642	11	640	34	.4606	20	53
8	676	27	631	11	674	33	.4586	20	52
9	703	27	620	11	707	34	.4566	21	51
10	.37730	27	.92609	11	.40741	34	2.4545	20	**50**
11	757	27	598	11	775	34	.4525	21	49
12	784	27	587	11	809	34	.4504	20	48
13	811	27	576	11	843	34	.4484	20	47
14	838	27	565	11	877	34	.4464	21	46
15	.37865	27	.92554	11	.40911	34	2.4443	20	**45**
16	892	27	543	11	945	34	.4423	20	44
17	919	27	532	11	979	34	.4403	20	43
18	946	27	521	11	.41013	34	.4383	21	42
19	973	26	510	11	047	34	.4362	20	41
20	.37999	27	.92499	11	.41081	34	2.4342	20	**40**
21	.38026	27	488	11	115	34	.4322	20	39
22	053	27	477	11	149	34	.4302	20	38
23	080	27	466	11	183	34	.4282	20	37
24	107	27	455	11	217	34	.4262	20	36
25	.38134	27	.92444	12	.41251	34	2.4242	20	**35**
26	161	27	432	11	285	34	.4222	20	34
27	188	27	421	11	319	34	.4202	20	33
28	215	26	410	11	353	34	.4182	20	32
29	241	27	399	11	387	34	.4162	20	31
30	.38268	27	.92388	11	.41421	34	2.4142	20	**30**
31	295	27	377	11	455	35	.4122	20	29
32	322	27	366	11	490	34	.4102	19	28
33	349	27	355	12	524	34	.4083	20	27
34	376	27	343	11	558	34	.4063	20	26
35	.38403	27	.92332	11	.41592	34	2.4043	20	**25**
36	430	26	321	11	626	34	.4023	19	24
37	456	27	310	11	660	34	.4004	20	23
38	483	27	299	12	694	34	.3984	20	22
39	510	27	287	11	728	35	.3964	19	21
40	.38537	27	.92276	11	.41763	34	2.3945	20	**20**
41	564	27	265	11	797	34	.3925	19	19
42	591	26	254	11	831	34	.3906	20	18
43	617	27	243	12	865	34	.3886	19	17
44	644	27	231	11	899	34	.3867	20	16
45	.38671	27	.92220	11	.41933	35	2.3847	19	**15**
46	698	27	209	11	968	34	.3828	20	14
47	725	27	198	12	.42002	34	.3808	19	13
48	752	26	186	11	036	34	.3789	19	12
49	778	27	175	11	070	35	.3770	20	11
50	.38805	27	.92164	12	.42105	34	2.3750	19	**10**
51	832	27	152	11	139	34	.3731	19	9
52	859	27	141	11	173	34	.3712	19	8
53	886	26	130	11	207	35	.3693	20	7
54	912	27	119	12	242	34	.3673	19	6
55	.38939	27	.92107	11	.42276	34	2.3654	19	**5**
56	966	27	096	11	310	35	.3635	19	4
57	993	27	085	12	345	34	.3616	19	3
58	.39020	26	073	11	379	34	.3597	19	2
59	046	27	062	12	413	34	.3578	19	1
60	.39073		.92050		.42447		2.3559		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

67°

P. P.

	21	20
1	0.4	0.3
2	0.7	0.7
3	1.0	1.0
4	1.4	1.3
5	1.8	1.7
6	2.1	2.0
7	2.4	2.3
8	2.8	2.7
9	3.2	3.0
10	3.5	3.3
20	7.0	6.7
30	10.5	10.0
40	14.0	13.3
50	17.5	16.7

	19	12
1	0.3	0.2
2	0.6	0.4
3	1.0	0.6
4	1.3	0.8
5	1.6	1.0
6	1.9	1.2
7	2.2	1.4
8	2.5	1.6
9	2.8	1.8
10	3.2	2.0
20	6.3	4.0
30	9.5	6.0
40	12.7	8.0
50	15.8	10.0

	11	10
1	0.2	0.2
2	0.4	0.3
3	0.6	0.5
4	0.7	0.7
5	0.9	0.8
6	1.1	1.0
7	1.3	1.2
8	1.5	1.3
9	1.6	1.5
10	1.8	1.7
20	3.7	3.3
30	5.5	5.0
40	7.3	6.7
50	9.2	8.3

P. P.

23°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.39073	27	.92050	11	.42447	35	2.3559	20	**60**
1	100	27	039	11	482	34	.3539	19	59
2	127	26	028	12	516	35	.3520	19	58
3	153	27	016	11	551	34	.3501	18	57
4	180	27	005	11	585	34	.3483	19	56
5	.39207	27	.91994	12	.42619	35	2.3464	19	**55**
6	234	26	982	11	654	34	.3445	19	54
7	260	27	971	12	688	34	.3426	19	53
8	287	27	959	11	722	35	.3407	19	52
9	314	27	948	12	757	34	.3388	19	51
10	.39341	26	.91936	11	.42791	35	2.3369	18	**50**
11	367	27	925	11	826	34	.3351	19	49
12	394	27	914	12	860	34	.3332	19	48
13	421	27	902	11	894	35	.3313	19	47
14	448	26	891	12	929	34	.3294	18	46
15	.39474	27	.91879	11	.42963	35	2.3276	19	**45**
16	501	27	868	12	998	34	.3257	19	44
17	528	27	856	11	.43032	35	.3238	18	43
18	555	26	845	12	067	34	.3220	19	42
19	581	27	833	11	101	35	.3201	18	41
20	.39608	27	.91822	12	.43136	34	2.3183	19	**40**
21	635	26	810	11	170	35	.3164	18	39
22	661	27	799	12	205	34	.3146	19	38
23	688	27	787	12	239	35	.3127	18	37
24	715	26	775	11	274	34	.3109	19	36
25	.39741	27	.91764	12	.43308	35	2.3090	18	**35**
26	768	27	752	11	343	35	.3072	19	34
27	795	27	741	12	378	34	.3053	18	33
28	822	26	729	11	412	35	.3035	18	32
29	848	27	718	12	447	34	.3017	19	31
30	.39875	27	.91706	12	.43481	35	2.2998	18	**30**
31	902	26	694	11	516	34	.2980	18	29
32	928	27	683	12	550	35	.2962	18	28
33	955	27	671	11	585	35	.2944	19	27
34	982	26	660	12	620	34	.2925	18	26
35	.40008	27	.91648	12	.43654	35	2.2907	18	**25**
36	035	27	636	11	689	35	.2889	18	24
37	062	26	625	12	724	34	.2871	18	23
38	088	27	613	12	758	35	.2853	18	22
39	115	26	601	11	793	35	.2835	18	21
40	.40141	27	.91590	12	.43828	34	2.2817	18	**20**
41	168	27	578	12	862	35	.2799	18	19
42	195	26	566	11	897	35	.2781	18	18
43	221	27	555	12	932	34	.2763	18	17
44	248	27	543	12	966	35	.2745	18	16
45	.40275	26	.91531	12	.44001	35	2.2727	18	**15**
46	301	27	519	11	036	35	.2709	18	14
47	328	27	508	12	071	34	.2691	18	13
48	355	26	496	12	105	35	.2673	18	12
49	381	27	484	12	140	35	.2655	18	11
50	.40408	26	.91472	11	.44175	35	2.2637	17	**10**
51	434	27	461	12	210	34	.2620	18	9
52	461	27	449	12	244	35	.2602	18	8
53	488	26	437	12	279	35	.2584	18	7
54	514	27	425	11	314	35	.2566	17	6
55	.40541	26	.91414	12	.44349	35	2.2549	18	**5**
56	567	27	402	12	384	34	.2531	18	4
57	594	27	390	12	418	35	.2513	17	3
58	621	26	378	12	453	35	.2496	18	2
59	647	27	366	11	488	35	.2478	18	1
60	.40674		.91355		.44523		2.2460		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

66°

P. P.

	36	35
1	0.6	0.6
2	1.2	1.2
3	1.8	1.8
4	2.4	2.3
5	3.0	2.9
6	3.6	3.5
7	4.2	4.1
8	4.8	4.7
9	5.4	5.2
10	6.0	5.8
20	12.0	11.7
30	18.0	17.5
40	24.0	23.3
50	30.0	29.2

	34	27
1	0.6	0.4
2	1.1	0.9
3	1.7	1.4
4	2.3	1.8
5	2.8	2.2
6	3.4	2.7
7	4.0	3.2
8	4.5	3.6
9	5.1	4.0
10	5.7	4.5
20	11.3	9.0
30	17.0	13.5
40	22.7	18.0
50	28.3	22.5

	26	20
1	0.4	0.3
2	0.9	0.7
3	1.3	1.0
4	1.7	1.3
5	2.2	1.7
6	2.6	2.0
7	3.0	2.3
8	3.5	2.7
9	3.9	3.0
10	4.3	3.3
20	8.7	6.7
30	13.0	10.0
40	17.3	13.3
50	21.7	16.7

	19	18
1	0.3	0.3
2	0.6	0.6
3	1.0	0.9
4	1.3	1.2
5	1.6	1.5
6	1.9	1.8
7	2.2	2.1
8	2.5	2.4
9	2.8	2.7
10	3.2	3.0
20	6.3	6.0
30	9.5	9.0
40	12.7	12.0
50	15.8	15.0

P. P.

24°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.40674	26	.91355	12	.44523	35	2.2460	17	**60**
1	700	27	343	12	558	35	.2443	18	59
2	727	26	331	12	593	34	.2425	17	58
3	753	27	319	12	627	35	.2408	18	57
4	780	26	307	12	662	35	.2390	17	56
5	.40806	27	.91295	12	.44697	35	2.2373	18	**55**
6	833	27	283	11	732	35	.2355	17	54
7	860	26	272	12	767	35	.2338	18	53
8	886	27	260	12	802	35	.2320	17	52
9	913	26	248	12	837	35	.2303	17	51
10	.40939	27	.91236	12	.44872	35	2.2286	18	**50**
11	966	26	224	12	907	35	.2268	17	49
12	992	27	212	12	942	35	.2251	17	48
13	.41019	26	200	12	977	35	.2234	18	47
14	045	27	188	12	.45012	35	.2216	17	46
15	.41072	26	.91176	12	.45047	35	2.2199	17	**45**
16	098	27	164	12	082	35	.2182	17	44
17	125	26	152	12	117	35	.2165	17	43
18	151	27	140	12	152	35	.2148	18	42
19	178	26	128	12	187	35	.2130	17	41
20	.41204	27	.91116	12	.45222	35	2.2113	17	**40**
21	231	26	104	12	257	35	.2096	17	39
22	257	27	092	12	292	35	.2079	17	38
23	284	26	080	12	327	35	.2062	17	37
24	310	27	068	12	362	35	.2045	17	36
25	.41337	26	.91056	12	.45397	35	2.2028	17	**35**
26	363	27	044	12	432	35	.2011	17	34
27	390	26	032	12	467	35	.1994	17	33
28	416	27	020	12	502	36	.1977	17	32
29	443	26	008	12	538	35	.1960	17	31
30	.41469	27	.90996	12	.45573	35	2.1943	17	**30**
31	496	26	984	12	608	35	.1926	17	29
32	522	27	972	12	643	35	.1909	17	28
33	549	26	960	12	678	35	.1892	16	27
34	575	27	948	12	713	35	.1876	17	26
35	.41602	26	.90936	12	.45748	36	2.1859	17	**25**
36	628	27	924	13	784	35	.1842	17	24
37	655	26	911	12	819	35	.1825	17	23
38	681	26	899	12	854	35	.1808	16	22
39	707	27	887	12	889	35	.1792	17	21
40	.41734	26	.90875	12	.45924	36	2.1775	17	**20**
41	760	27	863	12	960	35	.1758	16	19
42	787	26	851	12	995	35	.1742	17	18
43	813	27	839	13	.46030	35	.1725	17	17
44	840	26	826	12	065	36	.1708	16	16
45	.41866	26	.90814	12	.46101	35	2.1692	17	**15**
46	892	27	802	12	136	35	.1675	16	14
47	919	26	790	12	171	35	.1659	17	13
48	945	27	778	12	206	36	.1642	17	12
49	972	26	766	13	242	35	.1625	16	11
50	.41998	26	.90753	12	.46277	35	2.1609	17	**10**
51	.42024	27	741	12	312	36	.1592	16	9
52	051	26	729	12	348	35	.1576	16	8
53	077	27	717	13	383	35	.1560	17	7
54	104	26	704	12	418	36	.1543	16	6
55	.42130	26	.90692	12	.46454	35	2.1527	17	**5**
56	156	27	680	12	489	36	.1510	16	4
57	183	26	668	13	525	35	.1494	16	3
58	209	26	655	12	560	35	.1478	17	2
59	235	27	643	12	595	36	.1461	16	1
60	.42262		.90631		.46631		2.1445		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

65°

P. P.

	17	16
1	0.3	0.3
2	0.6	0.5
3	0.8	0.8
4	1.1	1.1
5	1.4	1.3
6	1.7	1.6
7	2.0	1.9
8	2.3	2.1
9	2.6	2.4
10	2.8	2.7
20	5.7	5.3
30	8.5	8.0
40	11.3	10.7
50	14.2	13.3

	13	12
1	0.2	0.2
2	0.4	0.4
3	0.6	0.6
4	0.9	0.8
5	1.1	1.0
6	1.3	1.2
7	1.5	1.4
8	1.7	1.6
9	2.0	1.8
10	2.2	2.0
20	4.3	4.0
30	6.5	6.0
40	8.7	8.0
50	10.8	10.0

	11
1	0.2
2	0.4
3	0.6
4	0.7
5	0.9
6	1.1
7	1.3
8	1.5
9	1.6
10	1.8
20	3.7
30	5.5
40	7.3
50	9.2

P. P.

25°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.42262	26	.90631	13	.46631	35	2.1445	16	**60**
1	288	27	618	12	666	36	.1429	16	59
2	315	26	606	12	702	35	.1413	17	58
3	341	26	594	12	737	35	.1396	16	57
4	367	27	582	13	772	36	.1380	16	56
5	.42394	26	.90569	12	.46808	35	2.1364	16	**55**
6	420	26	557	12	843	36	.1348	16	54
7	446	27	545	13	879	35	.1332	17	53
8	473	26	532	12	914	36	.1315	16	52
9	499	26	520	13	950	35	.1299	16	51
10	.42525	27	.90507	12	.46985	36	2.1283	16	**50**
11	552	26	495	12	.47021	35	.1267	16	49
12	578	26	483	13	056	36	.1251	16	48
13	604	27	470	12	092	36	.1235	16	47
14	631	26	458	12	128	35	.1219	16	46
15	.42657	26	.90446	13	.47163	36	2.1203	16	**45**
16	683	26	433	12	199	35	.1187	16	44
17	709	27	421	13	234	36	.1171	16	43
18	736	26	408	12	270	35	.1155	16	42
19	762	26	396	13	305	36	.1139	16	41
20	.42788	27	.90383	12	.47341	36	2.1123	16	**40**
21	815	26	371	13	377	35	.1107	15	39
22	841	26	358	12	412	36	.1092	16	38
23	867	27	346	12	448	35	.1076	16	37
24	894	26	334	13	483	36	.1060	16	36
25	.42920	26	.90321	12	.47519	36	2.1044	16	**35**
26	946	26	309	13	555	35	.1028	15	34
27	972	27	296	12	590	36	.1013	16	33
28	999	26	284	13	626	36	.0997	16	32
29	.43025	26	271	12	662	36	.0981	16	31
30	.43051	26	.90259	13	.47698	35	2.0965	15	**30**
31	077	27	246	13	733	36	.0950	16	29
32	104	26	233	12	769	36	.0934	16	28
33	130	26	221	13	805	35	.0918	15	27
34	156	26	208	12	840	36	.0903	16	26
35	.43182	27	.90196	13	.47876	36	2.0887	15	**25**
36	209	26	183	12	912	36	.0872	16	24
37	235	26	171	13	948	36	.0856	16	23
38	261	26	158	12	984	35	.0840	15	22
39	287	26	146	13	.48019	36	.0825	16	21
40	.43313	27	.90133	13	.48055	36	2.0809	15	**20**
41	340	26	120	12	091	36	.0794	16	19
42	366	26	108	13	127	36	.0778	15	18
43	392	26	095	13	163	35	.0763	15	17
44	418	27	082	12	198	36	.0748	16	16
45	.43445	26	.90070	13	.48234	36	2.0732	15	**15**
46	471	26	057	12	270	36	.0717	16	14
47	497	26	045	13	306	36	.0701	15	13
48	523	26	032	13	342	36	.0686	15	12
49	549	26	019	12	378	36	.0671	16	11
50	.43575	27	.90007	13	.48414	36	2.0655	15	**10**
51	602	26	.89994	13	450	36	.0640	15	9
52	628	26	981	13	486	35	.0625	16	8
53	654	26	968	12	521	36	.0609	15	7
54	680	26	956	13	557	36	.0594	15	6
55	.43706	27	.89943	13	.48593	36	2.0579	15	**5**
56	733	26	930	12	629	36	.0564	15	4
57	759	26	918	13	665	36	.0549	16	3
58	785	26	905	13	701	36	.0533	15	2
59	811	26	892	13	737	36	.0518	15	1
60	.43837		.89879		.48773		2.0503		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

64°

P. P.

	37	36
1	0.6	0.6
2	1.2	1.2
3	1.8	1.8
4	2.5	2.4
5	3.1	3.0
6	3.7	3.6
7	4.3	4.2
8	4.9	4.8
9	5.6	5.4
10	6.2	6.0
20	12.3	12.0
30	18.5	18.0
40	24.7	24.0
50	30.8	30.0

	35	27
1	0.6	0.4
2	1.2	0.9
3	1.8	1.4
4	2.3	1.8
5	2.9	2.2
6	3.5	2.7
7	4.1	3.2
8	4.7	3.6
9	5.2	4.0
10	5.8	4.5
20	11.7	9.0
30	17.5	13.5
40	23.3	18.0
50	29.2	22.5

	26	25
1	0.4	0.4
2	0.9	0.8
3	1.3	1.2
4	1.7	1.7
5	2.2	2.1
6	2.6	2.5
7	3.0	2.9
8	3.5	3.3
9	3.9	3.8
10	4.3	4.2
20	8.7	8.3
30	13.0	12.5
40	17.3	16.7
50	21.7	20.8

P. P.

26°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.43837	26	.89879	12	.48773	36	2.0503	15	**60**
1	863	26	867	13	809	36	.0488	15	59
2	889	27	854	13	845	36	.0473	15	58
3	916	26	841	13	881	36	.0458	15	57
4	942	26	828	12	917	36	.0443	15	56
5	.43968	26	.89816	13	.48953	36	2.0428	15	**55**
6	994	26	803	13	989	37	.0413	15	54
7	.44020	26	790	13	.49026	36	.0398	15	53
8	046	26	777	13	062	36	.0383	15	52
9	072	26	764	12	098	36	.0368	15	51
10	.44098	26	.89752	13	.49134	36	2.0353	15	**50**
11	124	27	739	13	170	36	.0338	15	49
12	151	26	726	13	206	36	.0323	15	48
13	177	26	713	13	242	36	.0308	15	47
14	203	26	700	13	278	37	.0293	15	46
15	.44229	26	.89687	13	.49315	36	2.0278	15	**45**
16	255	26	674	12	351	36	.0263	15	44
17	281	26	662	13	387	36	.0248	15	43
18	307	26	649	13	423	36	.0233	14	42
19	333	26	636	13	459	36	.0219	15	41
20	.44359	26	.89623	13	.49495	37	2.0204	15	**40**
21	385	26	610	13	532	36	.0189	15	39
22	411	26	597	13	568	36	.0174	14	38
23	437	27	584	13	604	36	.0160	15	37
24	464	26	571	13	640	37	.0145	15	36
25	.44490	26	.89558	13	.49677	36	2.0130	15	**35**
26	516	26	545	13	713	36	.0115	14	34
27	542	26	532	13	749	37	.0101	15	33
28	568	26	519	13	786	36	.0086	14	32
29	594	26	506	13	822	36	.0072	15	31
30	.44620	26	.89493	13	.49858	36	2.0057	15	**30**
31	646	26	480	13	894	37	.0042	14	29
32	672	26	467	13	931	36	.0028	15	28
33	698	26	454	13	967	37	.0013	14	27
34	724	26	441	13	.50004	36	1.9999	15	26
35	.44750	26	.89428	13	.50040	36	1.9984	14	**25**
36	776	26	415	13	076	37	.9970	15	24
37	802	26	402	13	113	36	.9955	14	23
38	828	26	389	13	149	36	.9941	15	22
39	854	26	376	13	185	37	.9926	14	21
40	.44880	26	.89363	13	.50222	36	1.9912	15	**20**
41	906	26	350	13	258	37	.9897	14	19
42	932	26	337	13	295	36	.9883	15	18
43	958	26	324	13	331	37	.9868	14	17
44	984	26	311	13	368	36	.9854	14	16
45	.45010	26	.89298	13	.50404	37	1.9840	15	**15**
46	036	26	285	13	441	36	.9825	14	14
47	062	26	272	13	477	37	.9811	14	13
48	088	26	259	14	514	36	.9797	15	12
49	114	26	245	13	550	37	.9782	14	11
50	.45140	26	.89232	13	.50587	36	1.9768	14	**10**
51	166	26	219	13	623	37	.9754	14	9
52	192	26	206	13	660	36	.9740	15	8
53	218	25	193	13	696	37	.9725	14	7
54	243	26	180	13	733	36	.9711	14	6
55	.45269	26	.89167	14	.50769	37	1.9697	14	**5**
56	295	26	153	13	806	37	.9683	14	4
57	321	26	140	13	843	36	.9669	15	3
58	347	26	127	13	879	37	.9654	14	2
59	373	26	114	13	916	37	.9640	14	1
60	.45399		.89101		.50953		1.9626		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

63°

P. P.

	17	16
1	0.3	0.3
2	0.6	0.5
3	0.8	0.8
4	1.1	1.1
5	1.4	1.3
6	1.7	1.6
7	2.0	1.9
8	2.3	2.1
9	2.6	2.4
10	2.8	2.7
20	5.7	5.3
30	8.5	8.0
40	11.3	10.7
50	14.2	13.3

	15	14
1	0.2	0.2
2	0.5	0.5
3	0.8	0.7
4	1.0	0.9
5	1.2	1.2
6	1.5	1.4
7	1.8	1.6
8	2.0	1.9
9	2.2	2.1
10	2.5	2.3
20	5.0	4.7
30	7.5	7.0
40	10.0	9.3
50	12.5	11.7

	13	12
1	0.2	0.2
2	0.4	0.4
3	0.6	0.6
4	0.9	0.8
5	1.1	1.0
6	1.3	1.2
7	1.5	1.4
8	1.7	1.6
9	2.0	1.8
10	2.2	2.0
20	4.3	4.0
30	6.5	6.0
40	8.7	8.0
50	10.8	10.0

P. P.

27°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.45399	26	.89101	14	.50953	36	1.9626	14	**60**
1	425	26	087	13	989	37	.9612	14	59
2	451	26	074	13	.51026	37	.9598	14	58
3	477	26	061	13	063	36	.9584	14	57
4	503	26	048	13	099	37	.9570	14	56
5	.45529	25	.89035	14	.51136	37	1.9556	14	**55**
6	554	26	021	13	173	36	.9542	14	54
7	580	26	008	13	209	37	.9528	14	53
8	606	26	.88995	14	246	37	.9514	14	52
9	632	26	981	13	283	36	.9500	14	51
10	.45658	26	.88968	13	.51319	37	1.9486	14	**50**
11	684	26	955	13	356	37	.9472	14	49
12	710	26	942	14	393	37	.9458	14	48
13	736	26	928	13	430	37	.9444	14	47
14	762	25	915	13	467	36	.9430	14	46
15	.45787	26	.88902	14	.51503	37	1.9416	14	**45**
16	813	26	888	13	540	37	.9402	14	44
17	839	26	875	13	577	37	.9388	13	43
18	865	26	862	14	614	37	.9375	14	42
19	891	26	848	13	651	37	.9361	14	41
20	.45917	25	.88835	13	.51688	36	1.9347	14	**40**
21	942	26	822	14	724	37	.9333	14	39
22	968	26	808	13	761	37	.9319	13	38
23	994	26	795	13	798	37	.9306	14	37
24	.46020	26	782	14	835	37	.9292	14	36
25	.46046	26	.88768	13	.51872	37	1.9278	13	**35**
26	072	25	755	14	909	37	.9265	14	34
27	097	26	741	13	946	37	.9251	14	33
28	123	26	728	13	983	37	.9237	14	32
29	149	26	715	14	.52020	37	.9223	13	31
30	.46175	26	.88701	13	.52057	37	1.9210	14	**30**
31	201	25	688	14	094	37	.9196	13	29
32	226	26	674	13	131	37	.9183	14	28
33	252	26	661	14	168	37	.9169	14	27
34	278	26	647	13	205	37	.9155	13	26
35	.46304	26	.88634	14	.52242	37	1.9142	14	**25**
36	330	25	620	13	279	37	.9128	13	24
37	355	26	607	14	316	37	.9115	14	23
38	381	26	593	13	353	37	.9101	13	22
39	407	26	580	14	390	37	.9088	14	21
40	.46433	25	.88566	13	.52427	37	1.9074	13	**20**
41	458	26	553	14	464	37	.9061	14	19
42	484	26	539	13	501	37	.9047	13	18
43	510	26	526	14	538	37	.9034	14	17
44	536	25	512	13	575	38	.9020	13	16
45	.46561	26	.88499	14	.52613	37	1.9007	14	**15**
46	587	26	485	13	650	37	.8993	13	14
47	613	26	472	14	687	37	.8980	13	13
48	639	25	458	13	724	37	.8967	14	12
49	664	26	445	14	761	37	.8953	13	11
50	.46690	26	.88431	14	.52798	38	1.8940	13	**10**
51	716	26	417	13	836	37	.8927	14	9
52	742	25	404	14	873	37	.8913	13	8
53	767	26	390	13	910	37	.8900	13	7
54	793	26	377	14	947	38	.8887	14	6
55	.46819	25	.88363	14	.52985	37	1.8873	13	**5**
56	844	26	349	13	.53022	37	.8860	13	4
57	870	26	336	14	059	37	.8847	13	3
58	896	25	322	14	096	38	.8834	14	2
59	921	26	308	13	134	37	.8820	13	1
60	.46947		.88295		.53171		1.8807		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

62°

P. P.

	38	37
1	0.6	0.6
2	1.3	1.2
3	1.9	1.8
4	2.5	2.5
5	3.2	3.1
6	3.8	3.7
7	4.4	4.3
8	5.1	4.9
9	5.7	5.6
10	6.3	6.2
20	12.7	12.3
30	19.0	18.5
40	25.3	24.7
50	31.7	30.8

	36	26
1	0.6	0.4
2	1.2	0.9
3	1.8	1.3
4	2.4	1.7
5	3.0	2.2
6	3.6	2.6
7	4.2	3.0
8	4.8	3.5
9	5.4	3.9
10	6.0	4.3
20	12.0	8.7
30	18.0	13.0
40	24.0	17.3
50	30.0	21.7

	25	15
1	0.4	0.2
2	0.8	0.5
3	1.2	0.8
4	1.7	1.0
5	2.1	1.2
6	2.5	1.5
7	2.9	1.8
8	3.3	2.0
9	3.8	2.2
10	4.2	2.5
20	8.3	5.0
30	12.5	7.5
40	16.7	10.0
50	20.8	12.5

P. P.

28°

P. P.

	14	13
1	0.2	0.2
2	0.5	0.4
3	0.7	0.6
4	0.9	0.9
5	1.2	1.1
6	1.4	1.3
7	1.6	1.5
8	1.9	1.7
9	2.1	2.0
10	2.3	2.2
20	4.7	4.3
30	7.0	6.5
40	9.3	8.7
50	11.7	10.8

	12
1	0.2
2	0.4
3	0.6
4	0.8
5	1.0
6	1.2
7	1.4
8	1.6
9	1.8
10	2.0
20	4.0
30	6.0
40	8.0
50	10.0

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.46947	26	.88295	14	.53171	37	1.8807	13	**60**
1	973	26	281	14	208	38	.8794	13	59
2	999	25	267	13	246	37	.8781	13	58
3	.47024	26	254	14	283	37	.8768	13	57
4	050	26	240	14	320	38	.8755	14	56
5	.47076	25	.88226	13	.53358	37	1.8741	13	**55**
6	101	26	213	14	395	37	.8728	13	54
7	127	26	199	14	432	38	.8715	13	53
8	153	25	185	13	470	37	.8702	13	52
9	178	26	172	14	507	38	.8689	13	51
10	.47204	25	.88158	14	.53545	37	1.8676	13	**50**
11	229	26	144	14	582	38	.8663	13	49
12	255	26	130	13	620	37	.8650	13	48
13	281	25	117	14	657	37	.8637	13	47
14	306	26	103	14	694	38	.8624	13	46
15	.47332	26	.88089	14	.53732	37	1.8611	13	**45**
16	358	25	075	13	769	38	.8598	13	44
17	383	26	062	14	807	37	.8585	13	43
18	409	25	048	14	844	38	.8572	13	42
19	434	26	034	14	882	38	.8559	13	41
20	.47460	26	.88020	14	.53920	37	1.8546	13	**40**
21	486	25	006	13	957	38	.8533	13	39
22	511	26	.87993	14	995	37	.8520	13	38
23	537	25	979	14	.54032	38	.8507	12	37
24	562	26	965	14	070	37	.8495	13	36
25	.47588	26	.87951	14	.54107	38	1.8482	13	**35**
26	614	25	937	14	145	38	.8469	13	34
27	639	26	923	14	183	37	.8456	13	33
28	665	25	909	13	220	38	.8443	13	32
29	690	26	896	14	258	38	.8430	12	31
30	.47716	25	.87882	14	.54296	37	1.8418	13	**30**
31	741	26	868	14	333	38	.8405	13	29
32	767	26	854	14	371	38	.8392	13	28
33	793	25	840	14	409	37	.8379	12	27
34	818	26	826	14	446	38	.8367	13	26
35	.47844	25	.87812	14	.54484	38	1.8354	13	**25**
36	869	26	798	14	522	38	.8341	12	24
37	895	25	784	14	560	37	.8329	13	23
38	920	26	770	14	597	38	.8316	13	22
39	946	25	756	13	635	38	.8303	12	21
40	.47971	26	.87743	14	.54673	38	1.8291	13	**20**
41	997	25	729	14	711	37	.8278	13	19
42	.48022	26	715	14	748	38	.8265	12	18
43	048	25	701	14	786	38	.8253	13	17
44	073	26	687	14	824	38	.8240	12	16
45	.48099	25	.87673	14	.54862	38	1.8228	13	**15**
46	124	26	659	14	900	38	.8215	13	14
47	150	25	645	14	938	37	.8202	12	13
48	175	26	631	14	975	38	.8190	13	12
49	201	25	617	14	.55013	38	.8177	12	11
50	.48226	26	.87603	14	.55051	38	1.8165	13	**10**
51	252	25	589	14	089	38	.8152	12	9
52	277	26	575	14	127	38	.8140	13	8
53	303	25	561	15	165	38	.8127	12	7
54	328	26	546	14	203	38	.8115	12	6
55	.48354	25	.87532	14	.55241	38	1.8103	13	**5**
56	379	26	518	14	279	38	.8090	12	4
57	405	25	504	14	317	38	.8078	13	3
58	430	26	490	14	355	38	.8065	12	2
59	456	25	476	14	393	38	.8053	13	1
60	.48481		.87462		.55431		1.8040		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

P. P.

61°

29°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	′
0	.48481	25	.87462	14	.55431	38	1.8040	12	**60**
1	506	26	448	14	469	38	.8028	12	59
2	532	25	434	14	507	38	.8016	13	58
3	557	26	420	14	545	38	.8003	12	57
4	583	25	406	15	583	38	.7991	12	56
5	.48608	26	.87391	14	.55621	38	1.7979	13	**55**
6	634	25	377	14	659	38	.7966	12	54
7	659	25	363	14	697	39	.7954	12	53
8	684	26	349	14	736	38	.7942	12	52
9	710	25	335	14	774	38	.7930	13	51
10	.48735	26	.87321	15	.55812	38	1.7917	12	**50**
11	761	25	306	14	850	38	.7905	12	49
12	786	25	292	14	888	38	.7893	12	48
13	811	26	278	14	926	38	.7881	13	47
14	837	25	264	14	964	39	.7868	12	46
15	.48862	26	.87250	15	.56003	38	1.7856	12	**45**
16	888	25	235	14	041	38	.7844	12	44
17	913	25	221	14	079	38	.7832	12	43
18	938	26	207	14	117	39	.7820	12	42
19	964	25	193	15	156	38	.7808	12	41
20	.48989	25	.87178	14	.56194	38	1.7796	13	**40**
21	.49014	26	164	14	232	38	.7783	12	39
22	040	25	150	14	270	39	.7771	12	38
23	065	25	136	15	309	38	.7759	12	37
24	090	26	121	14	347	38	.7747	12	36
25	.49116	25	.87107	14	.56385	39	1.7735	12	**35**
26	141	25	093	14	424	38	.7723	12	34
27	166	26	079	15	462	39	.7711	12	33
28	192	25	064	14	501	38	.7699	12	32
29	217	25	050	14	539	38	.7687	12	31
30	.49242	26	.87036	15	.56577	39	1.7675	12	**30**
31	268	25	021	14	616	38	.7663	12	29
32	293	25	007	14	654	39	.7651	12	28
33	318	26	.86993	15	693	38	.7639	12	27
34	344	25	978	14	731	38	.7627	12	26
35	.49369	25	.86964	15	.56769	39	1.7615	12	**25**
36	394	25	949	14	808	38	.7603	12	24
37	419	26	935	14	846	39	.7591	12	23
38	445	25	921	15	885	38	.7579	12	22
39	470	25	906	14	923	39	.7567	11	21
40	.49495	26	.86892	14	.56962	38	1.7556	12	**20**
41	521	25	878	15	.57000	39	.7544	12	19
42	546	25	863	14	039	39	.7532	12	18
43	571	25	849	15	078	38	.7520	12	17
44	596	26	834	14	116	39	.7508	12	16
45	.49622	25	.86820	15	.57155	38	1.7496	11	**15**
46	647	25	805	14	193	39	.7485	12	14
47	672	25	791	14	232	39	.7473	12	13
48	697	26	777	15	271	38	.7461	12	12
49	723	25	762	14	309	39	.7449	12	11
50	.49748	25	.86748	15	.57348	38	1.7437	11	**10**
51	773	25	733	14	386	39	.7426	12	9
52	798	26	719	15	425	39	.7414	12	8
53	824	25	704	14	464	39	.7402	11	7
54	849	25	690	15	503	38	.7391	12	6
55	.49874	25	.86675	14	.57541	39	1.7379	12	**5**
56	899	25	661	15	580	39	.7367	12	4
57	924	26	646	14	619	38	.7355	11	3
58	950	25	632	15	657	39	.7344	12	2
59	975	25	617	14	696	39	.7332	11	1
60	.50000		.86603		.57735		1.7321		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

60°

P. P.

	40	39	38	26	25	15
1	0.7	0.6	0.6	0.4	0.4	0.2
2	1.3	1.3	1.3	0.9	0.8	0.5
3	2.0	2.0	1.9	1.3	1.2	0.8
4	2.7	2.6	2.5	1.7	1.7	1.0
5	3.3	3.2	3.2	2.2	2.1	1.2
6	4.0	3.9	3.8	2.6	2.5	1.5
7	4.7	4.6	4.4	3.0	2.9	1.8
8	5.3	5.2	5.1	3.5	3.3	2.0
9	6.0	5.8	5.7	3.9	3.8	2.2
10	6.7	6.5	6.3	4.3	4.2	2.5
20	13.3	13.0	12.7	8.7	8.3	5.0
30	20.0	19.5	19.0	13.0	12.5	7.5
40	26.7	26.0	25.3	17.3	16.7	10.0
50	33.3	32.5	31.7	21.7	20.8	12.5

30°

P. P.

	14	13
1	0.2	0.2
2	0.5	0.4
3	0.7	0.6
4	0.9	0.9
5	1.2	1.1
6	1.4	1.3
7	1.6	1.5
8	1.9	1.7
9	2.1	2.0
10	2.3	2.2
20	4.7	4.3
30	7.0	6.5
40	9.3	8.7
50	11.7	10.8

	12	11
1	0.2	0.2
2	0.4	0.4
3	0.6	0.6
4	0.8	0.7
5	1.0	0.9
6	1.2	1.1
7	1.4	1.3
8	1.6	1.5
9	1.8	1.6
10	2.0	1.8
20	4.0	3.7
30	6.0	5.5
40	8.0	7.3
50	10.0	9.2

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.50000	25	.86603	15	.57735	39	1.7321	12	**60**
1	025	25	588	15	774	39	.7309	12	59
2	050	26	573	14	813	38	.7297	11	58
3	076	25	559	15	851	39	.7286	12	57
4	101	25	544	14	890	39	.7274	12	56
5	.50126	25	.86530	15	.57929	39	1.7262	11	**55**
6	151	25	515	14	968	39	.7251	12	54
7	176	25	501	15	.58007	39	.7239	11	53
8	201	26	486	15	046	39	.7228	12	52
9	227	25	471	14	085	39	.7216	11	51
10	.50252	25	.86457	15	.58124	38	1.7205	12	**50**
11	277	25	442	15	162	39	.7193	11	49
12	302	25	427	14	201	39	.7182	12	48
13	327	25	413	15	240	39	.7170	11	47
14	352	25	398	14	279	39	.7159	12	46
15	.50377	26	.86384	15	.58318	39	1.7147	11	**45**
16	403	25	369	15	357	39	.7136	12	44
17	428	25	354	14	396	39	.7124	11	43
18	453	25	340	15	435	39	.7113	11	42
19	478	25	325	15	474	39	.7102	12	41
20	.50503	25	.86310	15	.58513	39	1.7090	11	**40**
21	528	25	295	14	552	39	.7079	12	39
22	553	25	281	15	591	40	.7067	11	38
23	578	25	266	15	631	39	.7056	11	37
24	603	25	251	14	670	39	.7045	12	36
25	.50628	26	.86237	15	.58709	39	1.7033	11	**35**
26	654	25	222	15	748	39	.7022	11	34
27	679	25	207	15	787	39	.7011	12	33
28	704	25	192	14	826	39	.6999	11	32
29	729	25	178	15	865	40	.6988	11	31
30	.50754	25	.86163	15	.58905	39	1.6977	12	**30**
31	779	25	148	15	944	39	.6965	11	29
32	804	25	133	14	983	39	.6954	11	28
33	829	25	119	15	.59022	39	.6943	11	27
34	854	25	104	15	061	40	.6932	12	26
35	.50879	25	.86089	15	.59101	39	1.6920	11	**25**
36	904	25	074	15	140	39	.6909	11	24
37	929	25	059	14	179	39	.6898	11	23
38	954	25	045	15	218	40	.6887	12	22
39	979	25	030	15	258	39	.6875	11	21
40	.51004	25	.86015	15	.59297	39	1.6864	11	**20**
41	029	25	000	15	336	40	.6853	11	19
42	054	25	.85985	15	376	39	.6842	11	18
43	079	25	970	14	415	39	.6831	11	17
44	104	25	956	15	454	40	.6820	12	16
45	.51129	25	.85941	15	.59494	39	1.6808	11	**15**
46	154	25	926	15	533	40	.6797	11	14
47	179	25	911	15	573	39	.6786	11	13
48	204	25	896	15	612	39	.6775	11	12
49	229	25	881	15	651	40	.6764	11	11
50	.51254	25	.85866	15	.59691	39	1.6753	11	**10**
51	279	25	851	15	730	40	.6742	11	9
52	304	25	836	15	770	39	.6731	11	8
53	329	25	821	15	809	40	.6720	11	7
54	354	25	806	14	849	39	.6709	11	6
55	.51379	25	.85792	15	.59888	40	1.6698	11	**5**
56	404	25	777	15	928	39	.6687	11	4
57	429	25	762	15	967	40	.6676	11	3
58	454	25	747	15	.60007	39	.6665	11	2
59	479	25	732	15	046	40	.6654	11	1
60	.51504		.85717		.60086		1.6643		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

P. P.

59°

31°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.51504	25	.85717	15	.60086	40	1.6643	11	**60**
1	529	25	702	15	126	39	.6632	11	59
2	554	25	687	15	165	40	.6621	11	58
3	579	25	672	15	205	40	.6610	11	57
4	604	24	657	15	245	39	.6599	11	56
5	.51628	25	.85642	15	.60284	40	1.6588	11	**55**
6	653	25	627	15	324	40	.6577	11	54
7	678	25	612	15	364	39	.6566	11	53
8	703	25	597	15	403	40	.6555	10	52
9	728	25	582	15	443	40	.6545	11	51
10	.51753	25	.85567	16	.60483	39	1.6534	11	**50**
11	778	25	551	15	522	40	.6523	11	49
12	803	25	536	15	562	40	.6512	11	48
13	828	24	521	15	602	40	.6501	11	47
14	852	25	506	15	642	39	.6490	11	46
15	.51877	25	.85491	15	.60681	40	1.6479	10	**45**
16	902	25	476	15	721	40	.6469	11	44
17	927	25	461	15	761	40	.6458	11	43
18	952	25	446	15	801	40	.6447	11	42
19	977	25	431	15	841	40	.6436	10	41
20	.52002	24	.85416	15	.60881	40	1.6426	11	**40**
21	026	25	401	16	921	39	.6415	11	39
22	051	25	385	15	960	40	.6404	11	38
23	076	25	370	15	.61000	40	.6393	10	37
24	101	25	355	15	040	40	.6383	11	36
25	.52126	25	.85340	15	.61080	40	1.6372	11	**35**
26	151	24	325	15	120	40	.6361	10	34
27	175	25	310	16	160	40	.6351	11	33
28	200	25	294	15	200	40	.6340	11	32
29	225	25	279	15	240	40	.6329	10	31
30	.52250	25	.85264	15	.61280	40	1.6319	11	**30**
31	275	24	249	15	320	40	.6308	11	29
32	299	25	234	16	360	40	.6297	10	28
33	324	25	218	15	400	40	.6287	11	27
34	349	25	203	15	440	40	.6276	11	26
35	.52374	25	.85188	15	.61480	40	1.6265	10	**25**
36	399	24	173	16	520	41	.6255	11	24
37	423	25	157	15	561	40	.6244	10	23
38	448	25	142	15	601	40	.6234	11	22
39	473	25	127	15	641	40	.6223	11	21
40	.52498	24	.85112	16	.61681	40	1.6212	10	**20**
41	522	25	096	15	721	40	.6202	11	19
42	547	25	081	15	761	40	.6191	10	18
43	572	25	066	15	801	41	.6181	11	17
44	597	24	051	16	842	40	.6170	10	16
45	.52621	25	.85035	15	.61882	40	1.6160	11	**15**
46	646	25	020	15	922	40	.6149	10	14
47	671	25	005	16	962	41	.6139	11	13
48	696	24	.84989	15	.62003	40	.6128	10	12
49	720	25	974	15	043	40	.6118	11	11
50	.52745	25	.84959	16	.62083	41	1.6107	10	**10**
51	770	24	943	15	124	40	.6097	10	9
52	794	25	928	15	164	40	.6087	11	8
53	819	25	913	16	204	41	.6076	10	7
54	844	25	897	15	245	40	.6066	11	6
55	.52869	24	.84882	16	.62285	40	1.6055	10	**5**
56	893	25	866	15	325	41	.6045	11	4
57	918	25	851	15	366	40	.6034	10	3
58	943	24	836	16	406	40	.6024	10	2
59	967	25	820	15	446	41	.6014	11	1
60	.52992		.84805		.62487		1.6003		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

58°

P. P.

	42	41
1	0.7	0.7
2	1.4	1.4
3	2.1	2.0
4	2.8	2.7
5	3.5	3.4
6	4.2	4.1
7	4.9	4.8
8	5.6	5.5
9	6.3	6.2
10	7.0	6.8
20	14.0	13.7
30	21.0	20.5
40	28.0	27.3
50	35.0	34.2

	40	39
1	0.7	0.6
2	1.3	1.3
3	2.0	2.0
4	2.7	2.6
5	3.3	3.2
6	4.0	3.9
7	4.7	4.6
8	5.3	5.2
9	6.0	5.8
10	6.7	6.5
20	13.3	13.0
30	20.0	19.5
40	26.7	26.0
50	33.3	32.5

	25	24
1	0.4	0.4
2	0.8	0.8
3	1.2	1.2
4	1.7	1.6
5	2.1	2.0
6	2.5	2.4
7	2.9	2.8
8	3.3	3.2
9	3.8	3.6
10	4.2	4.0
20	8.3	8.0
30	12.5	12.0
40	16.7	16.0
50	20.8	20.0

P. P.

32°

P. P.

	16	15
1	0.3	0.2
2	0.5	0.5
3	0.8	0.8
4	1.1	1.0
5	1.3	1.2
6	1.6	1.5
7	1.9	1.8
8	2.1	2.0
9	2.4	2.2
10	2.7	2.5
20	5.3	5.0
30	8.0	7.5
40	10.7	10.0
50	13.3	12.5

	11	10
1	0.2	0.2
2	0.4	0.3
3	0.6	0.5
4	0.7	0.7
5	0.9	0.8
6	1.1	1.0
7	1.3	1.2
8	1.5	1.3
9	1.6	1.5
10	1.8	1.7
20	3.7	3.3
30	5.5	5.0
40	7.3	6.7
50	9.2	8.3

	9
1	0.2
2	0.3
3	0.4
4	0.6
5	0.8
6	0.9
7	1.0
8	1.2
9	1.4
10	1.5
20	3.0
30	4.5
40	6.0
50	7.5

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.52992	25	.84805	16	.62487	40	1.6003	10	**60**
1	.53017	24	789	15	527	41	.5993	10	59
2	041	25	774	15	568	40	.5983	11	58
3	066	25	759	16	608	41	.5972	10	57
4	091	24	743	15	649	40	.5962	10	56
5	.53115	25	.84728	16	.62689	41	1.5952	11	**55**
6	140	24	712	15	730	40	.5941	10	54
7	164	25	697	16	770	41	.5931	10	53
8	189	25	681	15	811	41	.5921	10	52
9	214	24	666	16	852	40	.5911	11	51
10	.53238	25	.84650	15	.62892	41	1.5900	10	**50**
11	263	25	635	16	933	40	.5890	10	49
12	288	24	619	15	973	41	.5880	11	48
13	312	25	604	16	.63014	41	.5869	10	47
14	337	24	588	15	055	40	.5859	10	46
15	.53361	25	.84573	16	.63095	41	1.5849	10	**45**
16	386	25	557	15	136	41	.5839	10	44
17	411	24	542	16	177	40	.5829	11	43
18	435	25	526	15	217	41	.5818	10	42
19	460	24	511	16	258	41	.5808	10	41
20	.53484	25	.84495	15	.63299	41	1.5798	10	**40**
21	509	25	480	16	340	40	.5788	10	39
22	534	24	464	16	380	41	.5778	10	38
23	558	25	448	15	421	41	.5768	11	37
24	583	24	433	16	462	41	.5757	10	36
25	.53607	25	.84417	15	.63503	41	1.5747	10	**35**
26	632	24	402	16	544	40	.5737	10	34
27	656	25	386	16	584	41	.5727	10	33
28	681	24	370	15	625	41	.5717	10	32
29	705	25	355	16	666	41	.5707	10	31
30	.53730	24	.84339	15	.63707	41	1.5697	10	**30**
31	754	25	324	16	748	41	.5687	10	29
32	779	25	308	16	789	41	.5677	10	28
33	804	24	292	15	830	41	.5667	10	27
34	828	25	277	16	871	41	.5657	10	26
35	.53853	24	.84261	16	.63912	41	1.5647	10	**25**
36	877	25	245	15	953	41	.5637	10	24
37	902	24	230	16	994	41	.5627	10	23
38	926	25	214	16	.64035	41	.5617	10	22
39	951	24	198	16	076	41	.5607	10	21
40	.53975	25	.84182	15	.64117	41	1.5597	10	**20**
41	.54000	24	167	16	158	41	.5587	10	19
42	024	25	151	16	199	41	.5577	10	18
43	049	24	135	15	240	41	.5567	10	17
44	073	24	120	16	281	41	.5557	10	16
45	.54097	25	.84104	16	.64322	41	1.5547	10	**15**
46	122	24	088	16	363	41	.5537	10	14
47	146	25	072	15	404	42	.5527	10	13
48	171	24	057	16	446	41	.5517	10	12
49	195	25	041	16	487	41	.5507	10	11
50	.54220	24	.84025	16	.64528	41	1.5497	10	**10**
51	244	25	009	15	569	41	.5487	10	9
52	269	24	.83994	16	610	42	.5477	9	8
53	293	24	978	16	652	41	.5468	10	7
54	317	25	962	16	693	41	.5458	10	6
55	.54342	24	.83946	16	.64734	41	1.5448	10	**5**
56	366	25	930	15	775	42	.5438	10	4
57	391	24	915	16	817	41	.5428	10	3
58	415	25	899	16	858	41	.5418	10	2
59	440	24	883	16	899	42	.5408	9	1
60	.54464		.83867		.64941		1.5399		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

P. P.

57°

33°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.54464	24	.83867	16	.64941	41	1.5399	10	60
1	488	25	851	16	982	42	.5389	10	59
2	513	24	835	16	.65024	41	.5379	10	58
3	537	24	819	15	065	41	.5369	10	57
4	561	25	804	16	106	42	.5359	9	56
5	.54586	24	.83788	16	.65148	41	1.5350	10	55
6	610	25	772	16	189	42	.5340	10	54
7	635	24	756	16	231	41	.5330	10	53
8	659	24	740	16	272	42	.5320	9	52
9	683	25	724	16	314	41	.5311	10	51
10	.54708	24	.83708	16	.65355	42	1.5301	10	50
11	732	24	692	16	397	41	.5291	9	49
12	756	25	676	16	438	42	.5282	10	48
13	781	24	660	15	480	41	.5272	10	47
14	805	24	645	16	521	42	.5262	9	46
15	.54829	25	.83629	16	.65563	41	1.5253	10	45
16	854	24	613	16	604	42	.5243	10	44
17	878	24	597	16	646	42	.5233	9	43
18	902	25	581	16	688	41	.5224	10	42
19	927	24	565	16	729	42	.5214	10	41
20	.54951	24	.83549	16	.65771	42	1.5204	9	40
21	975	24	533	16	813	41	.5195	10	39
22	999	25	517	16	854	42	.5185	10	38
23	.55024	24	501	16	896	42	.5175	9	37
24	048	24	485	16	938	42	.5166	10	36
25	.55072	25	.83469	16	.65980	41	1.5156	9	35
26	097	24	453	16	.66021	42	.5147	10	34
27	121	24	437	16	063	42	.5137	10	33
28	145	24	421	16	105	42	.5127	9	32
29	169	25	405	16	147	42	.5118	10	31
30	.55194	24	.83389	16	.66189	41	1.5108	9	30
31	218	24	373	17	230	42	.5099	10	29
32	242	24	356	16	272	42	.5089	9	28
33	266	25	340	16	314	42	.5080	10	27
34	291	24	324	16	356	42	.5070	9	26
35	.55315	24	.83308	16	.66398	42	1.5061	10	25
36	339	24	292	16	440	42	.5051	9	24
37	363	25	276	16	482	42	.5042	10	23
38	388	24	260	16	524	42	.5032	9	22
39	412	24	244	16	566	42	.5023	10	21
40	.55436	24	.83228	16	.66608	42	1.5013	9	20
41	460	24	212	17	650	42	.5004	10	19
42	484	25	195	16	692	42	.4994	9	18
43	509	24	179	16	734	42	.4985	10	17
44	533	24	163	16	776	42	.4975	9	16
45	.55557	24	.83147	16	.66818	42	1.4966	9	15
46	581	24	131	16	860	42	.4957	10	14
47	605	25	115	17	902	42	.4947	9	13
48	630	24	098	16	944	42	.4938	10	12
49	654	24	082	16	986	42	.4928	9	11
50	.55678	24	.83066	16	.67028	43	1.4919	9	10
51	702	24	050	16	071	42	.4910	10	9
52	726	24	034	17	113	42	.4900	9	8
53	750	25	017	16	155	42	.4891	9	7
54	775	24	001	16	197	42	.4882	10	6
55	.55799	24	.82985	16	.67239	43	1.4872	9	5
56	823	24	969	16	282	42	.4863	9	4
57	847	24	953	17	324	42	.4854	10	3
58	871	24	936	16	366	43	.4844	9	2
59	895	24	920	16	409	42	.4835	9	1
60	.55919		.82904		.67451		1.4826		0
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

56°

P. P.

	44	43
1	0.7	0.7
2	1.5	1.4
3	2.2	2.2
4	2.9	2.9
5	3.7	3.6
6	4.4	4.3
7	5.1	5.0
8	5.9	5.7
9	6.6	6.4
10	7.3	7.2
20	14.7	14.3
30	22.0	21.5
40	29.3	28.7
50	36.7	35.8

	42	41
1	0.7	0.7
2	1.4	1.4
3	2.1	2.0
4	2.8	2.7
5	3.5	3.4
6	4.2	4.1
7	4.9	4.8
8	5.6	5.5
9	6.3	6.2
10	7.0	6.8
20	14.0	13.7
30	21.0	20.5
40	28.0	27.3
50	35.0	34.2

	25	24
1	0.4	0.4
2	0.8	0.8
3	1.2	1.2
4	1.7	1.6
5	2.1	2.0
6	2.5	2.4
7	2.9	2.8
8	3.3	3.2
9	3.8	3.6
10	4.2	4.0
20	8.3	8.0
30	12.5	12.0
40	16.7	16.0
50	20.8	20.0

	23	17
1	0.4	0.3
2	0.8	0.6
3	1.2	0.8
4	1.5	1.1
5	1.9	1.4
6	2.3	1.7
7	2.7	2.0
8	3.1	2.3
9	3.4	2.6
10	3.8	2.8
20	7.7	5.7
30	11.5	8.5
40	15.3	11.3
50	19.2	14.2

34°

P. P.

	16	15
1	0.3	0.2
2	0.5	0.5
3	0.8	0.8
4	1.1	1.0
5	1.3	1.2
6	1.6	1.5
7	1.9	1.8
8	2.1	2.0
9	2.4	2.2
10	2.7	2.5
20	5.3	5.0
30	8.0	7.5
40	10.7	10.0
50	13.3	12.5

	10	9
1	0.2	0.2
2	0.3	0.3
3	0.5	0.4
4	0.7	0.6
5	0.8	0.8
6	1.0	0.9
7	1.2	1.0
8	1.3	1.2
9	1.5	1.4
10	1.7	1.5
20	3.3	3.0
30	5.0	4.5
40	6.7	6.0
50	8.3	7.5

	8
1	0.1
2	0.3
3	0.4
4	0.5
5	0.7
6	0.8
7	0.9
8	1.1
9	1.2
10	1.3
20	2.7
30	4.0
40	5.3
50	6.7

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.55919	24	.82904	17	.67451	42	1.4826	10	**60**
1	943	25	887	16	493	43	.4816	9	59
2	968	24	871	16	536	42	.4807	9	58
3	992	24	855	16	578	42	.4798	10	57
4	.56016	24	839	17	620	43	.4788	9	56
5	.56040	24	.82822	16	.67663	42	1.4779	9	**55**
6	064	24	806	16	705	43	.4770	9	54
7	088	24	790	17	748	42	.4761	10	53
8	112	24	773	16	790	42	.4751	9	52
9	136	24	757	16	832	43	.4742	9	51
10	.56160	24	.82741	17	.67875	42	1.4733	9	**50**
11	184	24	724	16	917	43	.4724	9	49
12	208	24	708	16	960	42	.4715	10	48
13	232	24	692	17	.68002	43	.4705	9	47
14	256	24	675	16	045	43	.4696	9	46
15	.56280	25	.82659	16	.68088	42	1.4687	9	**45**
16	305	24	643	17	130	43	.4678	9	44
17	329	24	626	16	173	42	.4669	10	43
18	353	24	610	17	215	43	.4659	9	42
19	377	24	593	16	258	43	.4650	9	41
20	.56401	24	.82577	16	.68301	42	1.4641	9	**40**
21	425	24	561	17	343	43	.4632	9	39
22	449	24	544	16	386	43	.4623	9	38
23	473	24	528	17	429	42	.4614	9	37
24	497	24	511	16	471	43	.4605	9	36
25	.56521	24	.82495	17	.68514	43	1.4596	10	**35**
26	545	24	478	16	557	43	.4586	9	34
27	569	24	462	16	600	42	.4577	9	33
28	593	24	446	17	642	43	.4568	9	32
29	617	24	429	16	685	43	.4559	9	31
30	.56641	24	.82413	17	.68728	43	1.4550	9	**30**
31	665	24	396	16	771	43	.4541	9	29
32	689	24	380	17	814	43	.4532	9	28
33	713	23	363	16	857	43	.4523	9	27
34	736	24	347	17	900	42	.4514	9	26
35	.56760	24	.82330	16	.68942	43	1.4505	9	**25**
36	784	24	314	17	985	43	.4496	9	24
37	808	24	297	16	.69028	43	.4487	9	23
38	832	24	281	17	071	43	.4478	9	22
39	856	24	264	16	114	43	.4469	9	21
40	.56880	24	.82248	17	.69157	43	1.4460	9	**20**
41	904	24	231	17	200	43	.4451	9	19
42	928	24	214	16	243	43	.4442	9	18
43	952	24	198	17	286	43	.4433	9	17
44	976	24	181	16	329	43	.4424	9	16
45	.57000	24	.82165	17	.69372	44	1.4415	9	**15**
46	024	23	148	16	416	43	.4406	9	14
47	047	24	132	17	459	43	.4397	9	13
48	071	24	115	17	502	43	.4388	9	12
49	095	24	098	16	545	43	.4379	9	11
50	.57119	24	.82082	17	.69588	43	1.4370	9	**10**
51	143	24	065	17	631	44	.4361	9	9
52	167	24	048	16	675	43	.4352	8	8
53	191	24	032	17	718	43	.4344	9	7
54	215	23	015	16	761	43	.4335	9	6
55	.57238	24	.81999	17	.69804	43	1.4326	9	**5**
56	262	24	982	17	847	44	.4317	9	4
57	286	24	965	16	891	43	.4308	9	3
58	310	24	949	17	934	43	.4299	9	2
59	334	24	932	17	977	44	.4290	9	1
60	.57358		.81915		.70021		1.4281		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

P. P.

55°

35°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	′
0	.57358	23	.81915	16	.70021	43	1.4281	8	60
1	381	24	899	17	064	43	.4273	9	59
2	405	24	882	17	107	44	.4264	9	58
3	429	24	865	17	151	43	.4255	9	57
4	453	24	848	16	194	44	.4246	9	56
5	.57477	24	.81832	17	.70238	43	1.4237	8	55
6	501	23	815	17	281	44	.4229	9	54
7	524	24	798	16	325	43	.4220	9	53
8	548	24	782	17	368	44	.4211	9	52
9	572	24	765	17	412	43	.4202	9	51
10	.57596	23	.81748	17	.70455	44	1.4193	8	50
11	619	24	731	17	499	43	.4185	9	49
12	643	24	714	16	542	44	.4176	9	48
13	667	24	698	17	586	43	.4167	9	47
14	691	24	681	17	629	44	.4158	8	46
15	.57715	23	.81664	17	.70673	44	1.4150	9	45
16	738	24	647	16	717	43	.4141	9	44
17	762	24	631	17	760	44	.4132	8	43
18	786	24	614	17	804	44	.4124	9	42
19	810	23	597	17	848	43	.4115	9	41
20	.57833	24	.81580	17	.70891	44	1.4106	9	40
21	857	24	563	17	935	44	.4097	8	39
22	881	23	546	16	979	44	.4089	9	38
23	904	24	530	17	.71023	43	.4080	9	37
24	928	24	513	17	066	44	.4071	8	36
25	.57952	24	.81496	17	.71110	44	1.4063	9	35
26	976	23	479	17	154	44	.4054	9	34
27	999	24	462	17	198	44	.4045	8	33
28	.58023	24	445	17	242	43	.4037	9	32
29	047	23	428	16	285	44	.4028	9	31
30	.58070	24	.81412	17	.71329	44	1.4019	8	30
31	094	24	395	17	373	44	.4011	9	29
32	118	23	378	17	417	44	.4002	8	28
33	141	24	361	17	461	44	.3994	9	27
34	165	24	344	17	505	44	.3985	9	26
35	.58189	23	.81327	17	.71549	44	1.3976	8	25
36	212	24	310	17	593	44	.3968	9	24
37	236	24	293	17	637	44	.3959	8	23
38	260	23	276	17	681	44	.3951	9	22
39	283	24	259	17	725	44	.3942	8	21
40	.58307	23	.81242	17	.71769	44	1.3934	9	20
41	330	24	225	17	813	44	.3925	9	19
42	354	24	208	17	857	44	.3916	8	18
43	378	23	191	17	901	45	.3908	9	17
44	401	24	174	17	946	44	.3899	8	16
45	.58425	24	.81157	17	.71990	44	1.3891	9	15
46	449	23	140	17	.72034	44	.3882	8	14
47	472	24	123	17	078	44	.3874	9	13
48	496	23	106	17	122	45	.3865	8	12
49	519	24	089	17	167	44	.3857	9	11
50	.58543	24	.81072	17	.72211	44	1.3848	8	10
51	567	23	055	17	255	44	.3840	9	9
52	590	24	038	17	299	45	.3831	8	8
53	614	23	021	17	344	44	.3823	9	7
54	637	24	004	17	388	44	.3814	8	6
55	.58661	23	.80987	17	.72432	45	1.3806	8	5
56	684	24	970	17	477	44	.3798	9	4
57	708	23	953	17	521	44	.3789	8	3
58	731	24	936	17	565	45	.3781	9	2
59	755	24	919	17	610	44	.3772	8	1
60	.58779		.80902		.72654		1.3764		0
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

54°

P. P.

	46	45	44	43	24	23
1	0.8	0.8	0.7	0.7	0.4	0.4
2	1.5	1.5	1.5	1.4	0.8	0.8
3	2.3	2.2	2.2	2.2	1.2	1.2
4	3.1	3.0	2.9	2.9	1.6	1.5
5	3.8	3.8	3.7	3.6	2.0	1.9
6	4.6	4.5	4.4	4.3	2.4	2.3
7	5.4	5.2	5.1	5.0	2.8	2.7
8	6.1	6.0	5.9	5.7	3.2	3.1
9	6.9	6.8	6.6	6.4	3.6	3.4
10	7.7	7.5	7.3	7.2	4.0	3.8
20	15.3	15.0	14.7	14.3	8.0	7.7
30	23.0	22.5	22.0	21.5	12.0	11.5
40	30.7	30.0	29.3	28.7	16.0	15.3
50	38.3	37.5	36.7	35.8	20.0	19.2

36°

P. P.

	18	17
1	0.3	0.3
2	0.6	0.6
3	0.9	0.8
4	1.2	1.1
5	1.5	1.4
6	1.8	1.7
7	2.1	2.0
8	2.4	2.3
9	2.7	2.6
10	3.0	2.8
20	6.0	5.7
30	9.0	8.5
40	12.0	11.3
50	15.0	14.2

	16	9
1	0.3	0.2
2	0.5	0.3
3	0.8	0.4
4	1.1	0.6
5	1.3	0.8
6	1.6	0.9
7	1.9	1.0
8	2.1	1.2
9	2.4	1.4
10	2.7	1.5
20	5.3	3.0
30	8.0	4.5
40	10.7	6.0
50	13.3	7.5

	8
1	0.1
2	0.3
3	0.4
4	0.5
5	0.7
6	0.8
7	0.9
8	1.1
9	1.2
10	1.3
20	2.7
30	4.0
40	5.3
50	6.7

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.58779	23	.80902	17	.72654	45	1.3764	9	60
1	802	24	885	18	699	44	.3755	8	59
2	826	23	867	17	743	45	.3747	8	58
3	849	24	850	17	788	44	.3739	9	57
4	873	23	833	17	832	45	.3730	8	56
5	.58896	24	.80816	17	.72877	44	1.3722	9	55
6	920	23	799	17	921	45	.3713	8	54
7	943	24	782	17	966	44	.3705	8	53
8	967	23	765	17	.73010	45	.3697	9	52
9	990	24	748	18	055	45	.3688	8	51
10	.59014	23	.80730	17	.73100	44	1.3680	8	50
11	037	24	713	17	144	45	.3672	9	49
12	061	23	696	17	189	45	.3663	8	48
13	084	24	679	17	234	44	.3655	8	47
14	108	23	662	18	278	45	.3647	9	46
15	.59131	23	.80644	17	.73323	45	1.3638	8	45
16	154	24	627	17	368	45	.3630	8	44
17	178	23	610	17	413	44	.3622	9	43
18	201	24	593	17	457	45	.3613	8	42
19	225	23	576	18	502	45	.3605	8	41
20	.59248	24	.80558	17	.73547	45	1.3597	9	40
21	272	23	541	17	592	45	.3588	8	39
22	295	23	524	17	637	44	.3580	8	38
23	318	24	507	18	681	45	.3572	8	37
24	342	23	489	17	726	45	.3564	9	36
25	.59365	24	.80472	17	.73771	45	1.3555	8	35
26	389	23	455	17	816	45	.3547	8	34
27	412	24	438	18	861	45	.3539	8	33
28	436	23	420	17	906	45	.3531	9	32
29	459	23	403	17	951	45	.3522	8	31
30	.59482	24	.80386	18	.73996	45	1.3514	8	30
31	506	23	368	17	.74041	45	.3506	8	29
32	529	23	351	17	086	45	.3498	8	28
33	552	24	334	18	131	45	.3490	9	27
34	576	23	316	17	176	45	.3481	8	26
35	.59599	23	.80299	17	.74221	46	1.3473	8	25
36	622	24	282	18	267	45	.3465	8	24
37	646	23	264	17	312	45	.3457	8	23
38	669	24	247	17	357	45	.3449	9	22
39	693	23	230	18	402	45	.3440	8	21
40	.59716	23	.80212	17	.74447	45	1.3432	8	20
41	739	24	195	17	492	46	.3424	8	19
42	763	23	178	18	538	45	.3416	8	18
43	786	23	160	17	583	45	.3408	8	17
44	809	23	143	18	628	46	.3400	8	16
45	.59832	24	.80125	17	.74674	45	1.3392	8	15
46	856	23	108	17	719	45	.3384	9	14
47	879	23	091	18	764	46	.3375	8	13
48	902	24	073	17	810	45	.3367	8	12
49	926	23	056	18	855	45	.3359	8	11
50	.59949	23	.80038	17	.74900	46	1.3351	8	10
51	972	23	021	18	946	45	.3343	8	9
52	995	24	003	17	991	46	.3335	8	8
53	.60019	23	.79986	18	.75037	45	.3327	8	7
54	042	23	968	17	082	46	.3319	8	6
55	.60065	24	.79951	17	.75128	45	1.3311	8	5
56	089	23	934	18	173	46	.3303	8	4
57	112	23	916	17	219	45	.3295	8	3
58	135	23	899	18	264	46	.3287	9	2
59	158	24	881	17	310	45	.3278	8	1
60	.60182		.79864		.75355		1.3270		0
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

P. P.

53°

37°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.60182	23	.79864	18	.75355	46	1.3270	8	**60**
1	205	23	846	17	401	46	.3262	8	59
2	228	23	829	18	447	45	.3254	8	58
3	251	23	811	18	492	46	.3246	8	57
4	274	24	793	17	538	46	.3238	8	56
5	.60298	23	.79776	18	.75584	45	1.3230	8	**55**
6	321	23	758	17	629	46	.3222	8	54
7	344	23	741	18	675	46	.3214	8	53
8	367	23	723	17	721	46	.3206	8	52
9	390	24	706	18	767	45	.3198	8	51
10	.60414	23	.79688	17	.75812	46	1.3190	8	**50**
11	437	23	671	18	858	46	.3182	7	49
12	460	23	653	18	904	46	.3175	8	48
13	483	23	635	17	950	46	.3167	8	47
14	506	23	618	18	996	46	.3159	8	46
15	.60529	24	.79600	17	.76042	46	1.3151	8	**45**
16	553	23	583	18	088	46	.3143	8	44
17	576	23	565	18	134	46	.3135	8	43
18	599	23	547	17	180	46	.3127	8	42
19	622	23	530	18	226	46	.3119	8	41
20	.60645	23	.79512	18	.76272	46	1.3111	8	**40**
21	668	23	494	17	318	46	.3103	8	39
22	691	23	477	18	364	46	.3095	8	38
23	714	24	459	18	410	46	.3087	8	37
24	738	23	441	17	456	46	.3079	7	36
25	.60761	23	.79424	18	.76502	46	1.3072	8	**35**
26	784	23	406	18	548	46	.3064	8	34
27	807	23	388	17	594	46	.3056	8	33
28	830	23	371	18	640	46	.3048	8	32
29	853	23	353	18	686	47	.3040	8	31
30	.60876	23	.79335	17	.76733	46	1.3032	8	**30**
31	899	23	318	18	779	46	.3024	7	29
32	922	23	300	18	825	46	.3017	8	28
33	945	23	282	18	871	47	.3009	8	27
34	968	23	264	17	918	46	.3001	8	26
35	.60991	24	.79247	18	.76964	46	1.2993	8	**25**
36	.61015	23	229	18	.77010	47	.2985	8	24
37	038	23	211	18	057	46	.2977	7	23
38	061	23	193	17	103	46	.2970	8	22
39	084	23	176	18	149	47	.2962	8	21
40	.61107	23	.79158	18	.77196	46	1.2954	8	**20**
41	130	23	140	18	242	47	.2946	8	19
42	153	23	122	17	289	46	.2938	7	18
43	176	23	105	18	335	47	.2931	8	17
44	199	23	087	18	382	46	.2923	8	16
45	.61222	23	.79069	18	.77428	47	1.2915	8	**15**
46	245	23	051	18	475	46	.2907	7	14
47	268	23	033	17	521	47	.2900	8	13
48	291	23	016	18	568	47	.2892	8	12
49	314	23	.78998	18	615	46	.2884	8	11
50	.61337	23	.78980	18	.77661	47	1.2876	7	**10**
51	360	23	962	18	708	46	.2869	8	9
52	383	23	944	18	754	47	.2861	8	8
53	406	23	926	18	801	47	.2853	7	7
54	429	22	908	17	848	47	.2846	8	6
55	.61451	23	.78891	18	.77895	46	1.2838	8	**5**
56	474	23	873	18	941	47	.2830	8	4
57	497	23	855	18	988	47	.2822	7	3
58	520	23	837	18	.78035	47	.2815	8	2
59	543	23	819	18	082	47	.2807	8	1
60	.61566		.78801		.78129		1.2799		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

52°

P. P.

	48	47
1	0.8	0.8
2	1.6	1.6
3	2.4	2.4
4	3.2	3.1
5	4.0	3.9
6	4.8	4.7
7	5.6	5.5
8	6.4	6.3
9	7.2	7.0
10	8.0	7.8
20	16.0	15.7
30	24.0	23.5
40	32.0	31.3
50	40.0	39.2

	46	45
1	0.8	0.8
2	1.5	1.5
3	2.3	2.2
4	3.1	3.0
5	3.8	3.8
6	4.6	4.5
7	5.4	5.2
8	6.1	6.0
9	6.9	6.8
10	7.7	7.5
20	15.3	15.0
30	23.0	22.5
40	30.7	30.0
50	38.3	37.5

	24	23
1	0.4	0.4
2	0.8	0.8
3	1.2	1.2
4	1.6	1.5
5	2.0	1.9
6	2.4	2.3
7	2.8	2.7
8	3.2	3.1
9	3.6	3.4
10	4.0	3.8
20	8.0	7.7
30	12.0	11.5
40	16.0	15.3
50	20.0	19.2

P. P.

38°

P. P.

	22	19
1	0.4	0.3
2	0.7	0.6
3	1.1	1.0
4	1.5	1.3
5	1.8	1.6
6	2.2	1.9
7	2.6	2.2
8	2.9	2.5
9	3.3	2.8
10	3.7	3.2
20	7.3	6.3
30	11.0	9.5
40	14.7	12.7
50	18.3	15.8

	18	17
1	0.3	0.3
2	0.6	0.6
3	0.9	0.8
4	1.2	1.1
5	1.5	1.4
6	1.8	1.7
7	2.1	2.0
8	2.4	2.3
9	2.7	2.6
10	3.0	2.8
20	6.0	5.7
30	9.0	8.5
40	12.0	11.3
50	15.0	14.2

	8	7
1	0.1	0.1
2	0.3	0.2
3	0.4	0.4
4	0.5	0.5
5	0.7	0.6
6	0.8	0.7
7	0.9	0.8
8	1.1	0.9
9	1.2	1.0
10	1.3	1.2
20	2.7	2.3
30	4.0	3.5
40	5.3	4.7
50	6.7	5.8

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.61566	23	.78801	18	.78129	46	1.2799	7	**60**
1	589	23	783	18	175	47	.2792	8	59
2	612	23	765	18	222	47	.2784	8	58
3	635	23	747	18	269	47	.2776	7	57
4	658	23	729	18	316	47	.2769	8	56
5	.61681	23	.78711	17	.78363	47	1.2761	8	**55**
6	704	22	694	18	410	47	.2753	7	54
7	726	23	676	18	457	47	.2746	8	53
8	749	23	658	18	504	47	.2738	7	52
9	772	23	640	18	551	47	.2731	8	51
10	.61795	23	.78622	18	.78598	47	1.2723	8	**50**
11	818	23	604	18	645	47	.2715	7	49
12	841	23	586	18	692	47	.2708	8	48
13	864	23	568	18	739	47	.2700	7	47
14	887	22	550	18	786	48	.2693	8	46
15	.61909	23	.78532	18	.78834	47	1.2685	8	**45**
16	932	23	514	18	881	47	.2677	7	44
17	955	23	496	18	928	47	.2670	8	43
18	978	23	478	18	975	47	.2662	7	42
19	.62001	23	460	18	.79022	48	.2655	8	41
20	.62024	22	.78442	18	.79070	47	1.2647	7	**40**
21	046	23	424	19	117	47	.2640	8	39
22	069	23	405	18	164	48	.2632	8	38
23	092	23	387	18	212	47	.2624	7	37
24	115	23	369	18	259	47	.2617	8	36
25	.62138	22	.78351	18	.79306	48	1.2609	7	**35**
26	160	23	333	18	354	47	.2602	8	34
27	183	23	315	18	401	48	.2594	7	33
28	206	23	297	18	449	47	.2587	8	32
29	229	22	279	18	496	48	.2579	7	31
30	.62251	23	.78261	18	.79544	47	1.2572	8	**30**
31	274	23	243	18	591	48	.2564	7	29
32	297	23	225	19	639	47	.2557	8	28
33	320	22	206	18	686	48	.2549	7	27
34	342	23	188	18	734	47	.2542	8	26
35	.62365	23	.78170	18	.79781	48	1.2534	7	**25**
36	388	23	152	18	829	48	.2527	8	24
37	411	22	134	18	877	47	.2519	7	23
38	433	23	116	18	924	48	.2512	8	22
39	456	23	098	19	972	48	.2504	7	21
40	.62479	23	.78079	18	.80020	47	1.2497	8	**20**
41	502	22	061	18	067	48	.2489	7	19
42	524	23	043	18	115	48	.2482	7	18
43	547	23	025	18	163	48	.2475	8	17
44	570	22	007	19	211	47	.2467	7	16
45	.62592	23	.77988	18	.80258	48	1.2460	8	**15**
46	615	23	970	18	306	48	.2452	7	14
47	638	22	952	18	354	48	.2445	8	13
48	660	23	934	18	402	48	.2437	7	12
49	683	23	916	19	450	48	.2430	7	11
50	.62706	22	.77897	18	.80498	48	1.2423	8	**10**
51	728	23	879	18	546	48	.2415	7	9
52	751	23	861	18	594	48	.2408	7	8
53	774	22	843	19	642	48	.2401	8	7
54	796	23	824	18	690	48	.2393	7	6
55	.62819	23	.77806	18	.80738	48	1.2386	8	**5**
56	842	22	788	19	786	48	.2378	7	4
57	864	23	769	18	834	48	.2371	7	3
58	887	22	751	18	882	48	.2364	8	2
59	909	23	733	18	930	48	.2356	7	1
60	.62932		.77715		.80978		1.2349		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

P. P.

51°

39°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.62932	23	.77715	19	.80978	49	1.2349	7	**60**
1	955	22	696	18	.81027	48	.2342	8	59
2	977	23	678	18	075	48	.2334	7	58
3	.63000	22	660	19	123	48	.2327	7	57
4	022	23	641	18	171	49	.2320	8	56
5	.63045	23	.77623	18	.81220	48	1.2312	7	**55**
6	068	22	605	19	268	48	.2305	7	54
7	090	23	586	18	316	48	.2298	8	53
8	113	22	568	18	364	49	.2290	7	52
9	135	23	550	19	413	48	.2283	7	51
10	.63158	22	.77531	18	.81461	49	1.2276	8	**50**
11	180	23	513	19	510	48	.2268	7	49
12	203	22	494	18	558	48	.2261	7	48
13	225	23	476	18	606	49	.2254	7	47
14	248	23	458	19	655	48	.2247	8	46
15	.63271	22	.77439	18	.81703	49	1.2239	7	**45**
16	293	23	421	19	752	48	.2232	7	44
17	316	22	402	18	800	49	.2225	7	43
18	338	23	384	18	849	49	.2218	8	42
19	361	22	366	19	898	48	.2210	7	41
20	.63383	23	.77347	18	.81946	49	1.2203	7	**40**
21	406	22	329	19	995	49	.2196	7	39
22	428	23	310	18	.82044	48	.2189	8	38
23	451	22	292	19	092	49	.2181	7	37
24	473	23	273	18	141	49	.2174	7	36
25	.63496	22	.77255	19	.82190	48	1.2167	7	**35**
26	518	22	236	18	238	49	.2160	7	34
27	540	23	218	19	287	49	.2153	8	33
28	563	22	199	18	336	49	.2145	7	32
29	585	23	181	19	385	49	.2138	7	31
30	.63608	22	.77162	18	.82434	49	1.2131	7	**30**
31	630	23	144	19	483	48	.2124	7	29
32	653	22	125	18	531	49	.2117	8	28
33	675	23	107	19	580	49	.2109	7	27
34	698	22	088	18	629	49	.2102	7	26
35	.63720	22	.77070	19	.82678	49	1.2095	7	**25**
36	742	23	051	18	727	49	.2088	7	24
37	765	22	033	19	776	49	.2081	7	23
38	787	23	014	18	825	49	.2074	8	22
39	810	22	.76996	19	874	49	.2066	7	21
40	.63832	22	.76977	18	.82923	49	1.2059	7	**20**
41	854	23	959	19	972	50	.2052	7	19
42	877	22	940	19	.83022	49	.2045	7	18
43	899	23	921	18	071	49	.2038	7	17
44	922	22	903	19	120	49	.2031	7	16
45	.63944	22	.76884	18	.83169	49	1.2024	7	**15**
46	966	23	866	19	218	50	.2017	8	14
47	989	22	847	19	268	49	.2009	7	13
48	.64011	22	828	18	317	49	.2002	7	12
49	033	23	810	19	366	49	.1995	7	11
50	.64056	22	.76791	19	.83415	50	1.1988	7	**10**
51	078	22	772	18	465	49	.1981	7	9
52	100	23	754	19	514	50	.1974	7	8
53	123	22	735	18	564	49	.1967	7	7
54	145	22	717	19	613	49	.1960	7	6
55	.64167	23	.76698	19	.83662	50	1.1953	7	**5**
56	190	22	679	18	712	49	.1946	7	4
57	212	22	661	19	761	50	.1939	7	3
58	234	22	642	19	811	49	.1932	7	2
59	256	23	623	19	860	50	.1925	7	1
60	.64279		.76604		.83910		1.1918		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

50°

P. P.

	51	50
1	0.8	0.8
2	1.7	1.7
3	2.6	2.5
4	3.4	3.3
5	4.2	4.2
6	5.1	5.0
7	6.0	5.8
8	6.8	6.7
9	7.6	7.5
10	8.5	8.3
20	17.0	16.7
30	25.5	25.0
40	34.0	33.3
50	42.5	41.7

	49	48
1	0.8	0.8
2	1.6	1.6
3	2.4	2.4
4	3.3	3.2
5	4.1	4.0
6	4.9	4.8
7	5.7	5.6
8	6.5	6.4
9	7.4	7.2
10	8.2	8.0
20	16.3	16.0
30	24.5	24.0
40	32.7	32.0
50	40.8	40.0

	23	22
1	0.4	0.4
2	0.8	0.7
3	1.2	1.1
4	1.5	1.5
5	1.9	1.8
6	2.3	2.2
7	2.7	2.6
8	3.1	2.9
9	3.4	3.3
10	3.8	3.7
20	7.7	7.3
30	11.5	11.0
40	15.3	14.7
50	19.2	18.3

P. P.

40°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.64279	22	.76604	18	.83910	50	1.1918	8	**60**
1	301	22	586	19	960	49	.1910	7	59
2	323	23	567	19	.84009	50	.1903	7	58
3	346	22	548	18	059	49	.1896	7	57
4	368	22	530	19	108	50	.1889	7	56
5	.64390	22	.76511	19	.84158	50	1.1882	7	**55**
6	412	23	492	19	208	50	.1875	7	54
7	435	22	473	18	258	49	.1868	7	53
8	457	22	455	19	307	50	.1861	7	52
9	479	22	436	19	357	50	.1854	7	51
10	.64501	23	.76417	19	.84407	50	1.1847	7	**50**
11	524	22	398	18	457	50	.1840	7	49
12	546	22	380	19	507	49	.1833	7	48
13	568	22	361	19	556	50	.1826	7	47
14	590	22	342	19	606	50	.1819	7	46
15	.64612	23	.76323	19	.84656	50	1.1812	6	**45**
16	635	22	304	18	706	50	.1806	7	44
17	657	22	286	19	756	50	.1799	7	43
18	679	22	267	19	806	50	.1792	7	42
19	701	22	248	19	856	50	.1785	7	41
20	.64723	23	.76229	19	.84906	50	1.1778	7	**40**
21	746	22	210	18	956	50	.1771	7	39
22	768	22	192	19	.85006	51	.1764	7	38
23	790	22	173	19	057	50	.1757	7	37
24	812	22	154	19	107	50	.1750	7	36
25	.64834	22	.76135	19	.85157	50	1.1743	7	**35**
26	856	22	116	19	207	50	.1736	7	34
27	878	23	097	19	257	51	.1729	7	33
28	901	22	078	19	308	50	.1722	7	32
29	923	22	059	18	358	50	.1715	7	31
30	.64945	22	.76041	19	.85408	50	1.1708	6	**30**
31	967	22	022	19	458	51	.1702	7	29
32	989	22	003	19	509	50	.1695	7	28
33	.65011	22	.75984	19	559	50	.1688	7	27
34	033	22	965	19	609	51	.1681	7	26
35	.65055	22	.75946	19	.85660	50	1.1674	7	**25**
36	077	23	927	19	710	51	.1667	7	24
37	100	22	908	19	761	50	.1660	7	23
38	122	22	889	19	811	51	.1653	6	22
39	144	22	870	19	862	50	.1647	7	21
40	.65166	22	.75851	19	.85912	51	1.1640	7	**20**
41	188	22	832	19	963	51	.1633	7	19
42	210	22	813	19	.86014	50	.1626	7	18
43	232	22	794	19	064	51	.1619	7	17
44	254	22	775	19	115	51	.1612	6	16
45	.65276	22	.75756	18	.86166	50	1.1606	7	**15**
46	298	22	738	19	216	51	.1599	7	14
47	320	22	719	19	267	51	.1592	7	13
48	342	22	700	20	318	50	.1585	7	12
49	364	22	680	19	368	51	.1578	7	11
50	.65386	22	.75661	19	.86419	51	1.1571	6	**10**
51	408	22	642	19	470	51	.1565	7	9
52	430	22	623	19	521	51	.1558	7	8
53	452	22	604	19	572	51	.1551	7	7
54	474	22	585	19	623	51	.1544	6	6
55	.65496	22	.75566	19	.86674	51	1.1538	7	**5**
56	518	22	547	19	725	51	.1531	7	4
57	540	22	528	19	776	51	.1524	7	3
58	562	22	509	19	827	51	.1517	7	2
59	584	22	490	19	878	51	.1510	6	1
60	.65606		.75471		.86929		1.1504		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

49°

P. P.

	20	19
1	0.3	0.3
2	0.7	0.6
3	1.0	1.0
4	1.3	1.3
5	1.7	1.6
6	2.0	1.9
7	2.3	2.2
8	2.7	2.5
9	3.0	2.8
10	3.3	3.2
20	6.7	6.3
30	10.0	9.5
40	13.3	12.7
50	16.7	15.8

	18	8
1	0.3	0.1
2	0.6	0.3
3	0.9	0.4
4	1.2	0.5
5	1.5	0.7
6	1.8	0.8
7	2.1	0.9
8	2.4	1.1
9	2.7	1.2
10	3.0	1.3
20	6.0	2.7
30	9.0	4.0
40	12.0	5.3
50	15.0	6.7

	7	6
1	0.1	0.1
2	0.2	0.2
3	0.4	0.3
4	0.5	0.4
5	0.6	0.5
6	0.7	0.6
7	0.8	0.7
8	0.9	0.8
9	1.0	0.9
10	1.2	1.0
20	2.3	2.0
30	3.5	3.0
40	4.7	4.0
50	5.8	5.0

P. P.

41°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.65606	22	.75471	19	.86929	51	1.1504	7	60
1	628	22	452	19	980	51	.1497	7	59
2	650	22	433	19	.87031	51	.1490	7	58
3	672	22	414	19	082	51	.1483	6	57
4	694	22	395	20	133	51	.1477	7	56
5	.65716	22	.75375	19	.87184	52	1.1470	7	55
6	738	21	356	19	236	51	.1463	7	54
7	759	22	337	19	287	51	.1456	6	53
8	781	22	318	19	338	51	.1450	7	52
9	803	22	299	19	389	52	.1443	7	51
10	.65825	22	.75280	19	.87441	51	1.1436	6	50
11	847	22	261	20	492	51	.1430	7	49
12	869	22	241	19	543	52	.1423	7	48
13	891	22	222	19	595	51	.1416	6	47
14	913	22	203	19	646	52	.1410	7	46
15	.65935	21	.75184	19	.87698	51	1.1403	7	45
16	956	22	165	19	749	52	.1396	7	44
17	978	22	146	20	801	51	.1389	6	43
18	.66000	22	126	19	852	52	.1383	7	42
19	022	22	107	19	904	51	.1376	7	41
20	.66044	22	.75088	19	.87955	52	1.1369	6	40
21	066	22	069	19	.88007	52	.1363	7	39
22	088	21	050	20	059	51	.1356	7	38
23	109	22	030	19	110	52	.1349	6	37
24	131	22	011	19	162	52	.1343	7	36
25	.66153	22	.74992	19	.88214	51	1.1336	7	35
26	175	22	973	20	265	52	.1329	6	34
27	197	21	953	19	317	52	.1323	7	33
28	218	22	934	19	369	52	.1316	6	32
29	240	22	915	19	421	52	.1310	7	31
30	.66262	22	.74896	20	.88473	51	1.1303	7	30
31	284	22	876	19	524	52	.1296	6	29
32	306	21	857	19	576	52	.1290	7	28
33	327	22	838	20	628	52	.1283	7	27
34	349	22	818	19	680	52	.1276	6	26
35	.66371	22	.74799	19	.88732	52	1.1270	7	25
36	393	21	780	20	784	52	.1263	6	24
37	414	22	760	19	836	52	.1257	7	23
38	436	22	741	19	888	52	.1250	7	22
39	458	22	722	19	940	52	.1243	6	21
40	.66480	21	.74703	20	.88992	53	1.1237	7	20
41	501	22	683	19	.89045	52	.1230	6	19
42	523	22	664	20	097	52	.1224	7	18
43	545	21	644	19	149	52	.1217	6	17
44	566	22	625	19	201	52	.1211	7	16
45	.66588	22	.74606	20	.89253	53	1.1204	7	15
46	610	22	586	19	306	52	.1197	6	14
47	632	21	567	19	358	52	.1191	7	13
48	653	22	548	20	410	53	.1184	6	12
49	675	22	528	19	463	52	.1178	7	11
50	.66697	21	.74509	20	.89515	52	1.1171	6	10
51	718	22	489	19	567	53	.1165	7	9
52	740	22	470	19	620	52	.1158	6	8
53	762	21	451	20	672	53	.1152	7	7
54	783	22	431	19	725	52	.1145	6	6
55	.66805	22	.74412	20	.89777	53	1.1139	7	5
56	827	21	392	19	830	53	.1132	6	4
57	848	22	373	20	883	52	.1126	7	3
58	870	21	353	19	935	53	.1119	6	2
59	891	22	334	20	988	52	.1113	7	1
60	.66913		.74314		.90040		1.1106		0
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

48°

P. P.

	55	54
1	0.9	0.9
2	1.8	1.8
3	2.8	2.7
4	3.7	3.6
5	4.6	4.5
6	5.5	5.4
7	6.4	6.3
8	7.3	7.2
9	8.2	8.1
10	9.2	9.0
20	18.3	18.0
30	27.5	27.0
40	36.7	36.0
50	45.8	45.0

	53	52
1	0.9	0.9
2	1.8	1.7
3	2.6	2.6
4	3.5	3.5
5	4.4	4.3
6	5.3	5.2
7	6.2	6.1
8	7.1	6.9
9	8.0	7.8
10	8.8	8.7
20	17.7	17.3
30	26.5	26.0
40	35.3	34.7
50	44.2	43.3

	51
1	0.8
2	1.7
3	2.6
4	3.4
5	4.2
6	5.1
7	6.0
8	6.8
9	7.6
10	8.5
20	17.0
30	25.5
40	34.0
50	42.5

P. P.

42°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.66913	22	.74314	19	.90040	53	1.1106	6	**60**
1	935	21	295	19	093	53	.1100	7	59
2	956	22	276	20	146	53	.1093	6	58
3	978	21	256	19	199	52	.1087	7	57
4	999	22	237	20	251	53	.1080	6	56
5	.67021	22	.74217	19	.90304	53	1.1074	7	**55**
6	043	21	198	20	357	53	.1067	6	54
7	064	22	178	19	410	53	.1061	7	53
8	086	21	159	20	463	53	.1054	6	52
9	107	22	139	19	516	53	.1048	7	51
10	.67129	22	.74120	20	.90569	52	1.1041	6	**50**
11	151	21	100	20	621	53	.1035	7	49
12	172	22	080	19	674	53	.1028	6	48
13	194	21	061	20	727	54	.1022	6	47
14	215	22	041	19	781	53	.1016	7	46
15	.67237	21	.74022	20	.90834	53	1.1009	6	**45**
16	258	22	002	19	887	53	.1003	7	44
17	280	21	.73983	20	940	53	.0996	6	43
18	301	22	963	19	993	53	.0990	7	42
19	323	21	944	20	.91046	53	.0983	6	41
20	.67344	22	.73924	20	.91099	54	1.0977	6	**40**
21	366	21	904	19	153	53	.0971	7	39
22	387	22	885	20	206	53	.0964	6	38
23	409	21	865	19	259	54	.0958	7	37
24	430	22	846	20	313	53	.0951	6	36
25	.67452	21	.73826	20	.91366	53	1.0945	6	**35**
26	473	22	806	19	419	54	.0939	7	34
27	495	21	787	20	473	53	.0932	6	33
28	516	22	767	20	526	54	.0926	7	32
29	538	21	747	19	580	53	.0919	6	31
30	.67559	21	.73728	20	.91633	54	1.0913	6	**30**
31	580	22	708	20	687	53	.0907	7	29
32	602	21	688	19	740	54	.0900	6	28
33	623	22	669	20	794	53	.0894	6	27
34	645	21	649	20	847	54	.0888	7	26
35	.67666	22	.73629	19	.91901	54	1.0881	6	**25**
36	688	21	610	20	955	53	.0875	6	24
37	709	21	590	20	.92008	54	.0869	7	23
38	730	22	570	19	062	54	.0862	6	22
39	752	21	551	20	116	54	.0856	6	21
40	.67773	22	.73531	20	.92170	54	1.0850	7	**20**
41	795	21	511	20	224	53	.0843	6	19
42	816	21	491	19	277	54	.0837	6	18
43	837	22	472	20	331	54	.0831	7	17
44	859	21	452	20	385	54	.0824	6	16
45	.67880	21	.73432	19	.92439	54	1.0818	6	**15**
46	901	22	413	20	493	54	.0812	7	14
47	923	21	393	20	547	54	.0805	6	13
48	944	21	373	20	601	54	.0799	6	12
49	965	22	353	20	655	54	.0793	7	11
50	.67987	21	.73333	19	.92709	54	1.0786	6	**10**
51	.68008	21	314	20	763	54	.0780	6	9
52	029	22	294	20	817	55	.0774	6	8
53	051	21	274	20	872	54	.0768	7	7
54	072	21	254	20	926	54	.0761	6	6
55	.68093	22	.73234	19	.92980	54	1.0755	6	**5**
56	115	21	215	20	.93034	54	.0749	7	4
57	136	21	195	20	088	55	.0742	6	3
58	157	22	175	20	143	54	.0736	6	2
59	179	21	155	20	197	55	.0730	6	1
60	.68200		.73135		.93252		1.0724		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

47°

P. P.

	22	21
1	0.4	0.4
2	0.7	0.7
3	1.1	1.0
4	1.5	1.4
5	1.8	1.8
6	2.2	2.1
7	2.6	2.4
8	2.9	2.8
9	3.3	3.2
10	3.7	3.5
20	7.3	7.0
30	11.0	10.5
40	14.7	14.0
50	18.3	17.5

	20	19
1	0.3	0.3
2	0.7	0.6
3	1.0	1.0
4	1.3	1.3
5	1.7	1.6
6	2.0	1.9
7	2.3	2.2
8	2.7	2.5
9	3.0	2.8
10	3.3	3.2
20	6.7	6.3
30	10.0	9.5
40	13.3	12.7
50	16.7	15.8

	7	6
1	0.1	0.1
2	0.2	0.2
3	0.4	0.3
4	0.5	0.4
5	0.6	0.5
6	0.7	0.6
7	0.8	0.7
8	0.9	0.8
9	1.0	0.9
10	1.2	1.0
20	2.3	2.0
30	3.5	3.0
40	4.7	4.0
50	5.8	5.0

P. P.

43°

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	′
0	.68200	21	.73135	19	.93252	54	1.0724	7	**60**
1	221	21	116	20	306	54	.0717	6	59
2	242	22	096	20	360	55	.0711	6	58
3	264	21	076	20	415	54	.0705	6	57
4	285	21	056	20	469	55	.0699	7	56
5	.68306	21	.73036	20	.93524	54	1.0692	6	**55**
6	327	22	016	20	578	55	.0686	6	54
7	349	21	.72996	20	633	55	.0680	6	53
8	370	21	976	19	688	54	.0674	6	52
9	391	21	957	20	742	55	.0668	7	51
10	.68412	22	.72937	20	.93797	55	1.0661	6	**50**
11	434	21	917	20	852	54	.0655	6	49
12	455	21	897	20	906	55	.0649	6	48
13	476	21	877	20	961	55	.0643	6	47
14	497	21	857	20	.94016	55	.0637	7	46
15	.68518	21	.72837	20	.94071	54	1.0630	6	**45**
16	539	22	817	20	125	55	.0624	6	44
17	561	21	797	20	180	55	.0618	6	43
18	582	21	777	20	235	55	.0612	6	42
19	603	21	757	20	290	55	.0606	7	41
20	.68624	21	.72737	20	.94345	55	1.0599	6	**40**
21	645	21	717	20	400	55	.0593	6	39
22	666	22	697	20	455	55	.0587	6	38
23	688	21	677	20	510	55	.0581	6	37
24	709	21	657	20	565	55	.0575	6	36
25	.68730	21	.72637	20	.94620	56	1.0569	7	**35**
26	751	21	617	20	676	55	.0562	6	34
27	772	21	597	20	731	55	.0556	6	33
28	793	21	577	20	786	55	.0550	6	32
29	814	21	557	20	841	55	.0544	6	31
30	.68835	22	.72537	20	.94896	56	1.0538	6	**30**
31	857	21	517	20	952	55	.0532	6	29
32	878	21	497	20	.95007	55	.0526	7	28
33	899	21	477	20	062	56	.0519	6	27
34	920	21	457	20	118	55	.0513	6	26
35	.68941	21	.72437	20	.95173	56	1.0507	6	**25**
36	962	21	417	20	229	55	.0501	6	24
37	983	21	397	20	284	56	.0495	6	23
38	.69004	21	377	20	340	55	.0489	6	22
39	025	21	357	20	395	56	.0483	6	21
40	.69046	21	.72337	20	.95451	55	1.0477	7	**20**
41	067	21	317	20	506	56	.0470	6	19
42	088	21	297	20	562	56	.0464	6	18
43	109	21	277	20	618	55	.0458	6	17
44	130	21	257	21	673	56	.0452	6	16
45	.69151	21	.72236	20	.95729	56	1.0446	6	**15**
46	172	21	216	20	785	56	.0440	6	14
47	193	21	196	20	841	56	.0434	6	13
48	214	21	176	20	897	55	.0428	6	12
49	235	21	156	20	952	56	.0422	6	11
50	.69256	21	.72136	20	.96008	56	1.0416	6	**10**
51	277	21	116	21	064	56	.0410	6	9
52	298	21	095	20	120	56	.0404	6	8
53	319	21	075	20	176	56	.0398	6	7
54	340	21	055	20	232	56	.0392	7	6
55	.69361	21	.72035	20	.96288	56	1.0385	6	**5**
56	382	21	015	20	344	56	.0379	6	4
57	403	21	.71995	21	400	57	.0373	6	3
58	424	21	974	20	457	56	.0367	6	2
59	445	21	954	20	513	56	.0361	6	1
60	.69466		.71934		.96569		1.0355		**0**
	Cos.	**d.**	**Sin.**	**d.**	**Cot.**	**d.**	**Tan.**	**d.**	**′**

46°

P. P.

	58	57
1	1.0	1.0
2	1.9	1.9
3	2.9	2.9
4	3.9	3.8
5	4.8	4.8
6	5.8	5.7
7	6.8	6.7
8	7.7	7.6
9	8.7	8.6
10	9.7	9.5
20	19.3	19.0
30	29.0	28.5
40	38.7	38.0
50	48.3	47.5

	56	55
1	0.9	0.9
2	1.9	1.8
3	2.8	2.8
4	3.7	3.7
5	4.7	4.6
6	5.6	5.5
7	6.5	6.4
8	7.5	7.3
9	8.4	8.2
10	9.3	9.2
20	18.7	18.3
30	28.0	27.5
40	37.3	36.7
50	46.7	45.8

	54
1	0.9
2	1.8
3	2.7
4	3.6
5	4.5
6	5.4
7	6.3
8	7.2
9	8.1
10	9.0
20	18.0
30	27.0
40	36.0
50	45.0

P. P.

44°

P. P.

	22	21
1	0.4	0.4
2	0.7	0.7
3	1.1	1.0
4	1.5	1.4
5	1.8	1.8
6	2.2	2.1
7	2.6	2.4
8	2.9	2.8
9	3.3	3.2
10	3.7	3.5
20	7.3	7.0
30	11.0	10.5
40	14.7	14.0
50	18.3	17.5

	20	7
1	0.3	0.1
2	0.7	0.2
3	1.0	0.4
4	1.3	0.5
5	1.7	0.6
6	2.0	0.7
7	2.3	0.8
8	2.7	0.9
9	3.0	1.0
10	3.3	1.2
20	6.7	2.3
30	10.0	3.5
40	13.3	4.7
50	16.7	5.8

	6	5
1	0.1	0.1
2	0.2	0.2
3	0.3	0.2
4	0.4	0.3
5	0.5	0.4
6	0.6	0.5
7	0.7	0.6
8	0.8	0.7
9	0.9	0.8
10	1.0	0.8
20	2.0	1.7
30	3.0	2.5
40	4.0	3.3
50	5.0	4.2

′	Sin.	d.	Cos.	d.	Tan.	d.	Cot.	d.	
0	.69466	21	.71934	20	.96569	56	1.0355	6	**60**
1	487	21	914	20	625	56	.0349	6	59
2	508	21	894	21	681	57	.0343	6	58
3	529	20	873	20	738	56	.0337	6	57
4	549	21	853	20	794	56	.0331	6	56
5	.69570	21	.71833	20	.96850	57	1.0325	6	**55**
6	591	21	813	21	907	56	.0319	6	54
7	612	21	792	20	963	57	.0313	6	53
8	633	21	772	20	.97020	56	.0307	6	52
9	654	21	752	20	076	57	.0301	6	51
10	.69675	21	.71732	21	.97133	56	1.0295	6	**50**
11	696	21	711	20	189	57	.0289	6	49
12	717	20	691	20	246	56	.0283	6	48
13	737	21	671	21	302	57	.0277	6	47
14	758	21	650	20	359	57	.0271	6	46
15	.69779	21	.71630	20	.97416	56	1.0265	6	**45**
16	800	21	610	20	472	57	.0259	6	44
17	821	21	590	21	529	57	.0253	6	43
18	842	20	569	20	586	57	.0247	6	42
19	862	21	549	20	643	57	.0241	6	41
20	.69883	21	.71529	21	.97700	56	1.0235	5	**40**
21	904	21	508	20	756	57	.0230	6	39
22	925	21	488	20	813	57	.0224	6	38
23	946	20	468	21	870	57	.0218	6	37
24	966	21	447	20	927	57	.0212	6	36
25	.69987	21	.71427	20	.97984	57	1.0206	6	**35**
26	.70008	21	407	21	.98041	57	.0200	6	34
27	029	20	386	20	098	57	.0194	6	33
28	049	21	366	21	155	58	.0188	6	32
29	070	21	345	20	213	57	.0182	6	31
30	.70091	21	.71325	20	.98270	57	1.0176	6	**30**
31	112	20	305	21	327	57	.0170	6	29
32	132	21	284	20	384	57	.0164	6	28
33	153	21	264	21	441	58	.0158	6	27
34	174	21	243	20	499	57	.0152	5	26
35	.70195	20	.71223	20	.98556	57	1.0147	6	**25**
36	215	21	203	21	613	58	.0141	6	24
37	236	21	182	20	671	57	.0135	6	23
38	257	20	162	21	728	58	.0129	6	22
39	277	21	141	20	786	57	.0123	6	21
40	.70298	21	.71121	21	.98843	58	1.0117	6	**20**
41	319	20	100	20	901	57	.0111	6	19
42	339	21	080	21	958	58	.0105	6	18
43	360	21	059	20	.99016	57	.0099	5	17
44	381	20	039	20	073	58	.0094	6	16
45	.70401	21	.71019	21	.99131	58	1.0088	6	**15**
46	422	21	.70998	20	189	58	.0082	6	14
47	443	20	978	21	247	57	.0076	6	13
48	463	21	957	20	304	58	.0070	6	12
49	484	21	937	21	362	58	.0064	6	11
50	.70505	20	.70916	20	.99420	58	1.0058	6	**10**
51	525	21	896	21	478	58	.0052	5	9
52	546	21	875	20	536	58	.0047	6	8
53	567	20	855	21	594	58	.0041	6	7
54	587	21	834	21	652	58	.0035	6	6
55	.70608	20	.70813	20	.99710	58	1.0029	6	**5**
56	628	21	793	21	768	58	.0023	6	4
57	649	21	772	20	826	58	.0017	5	3
58	670	20	752	21	884	58	.0012	6	2
59	690	21	731	20	942	58	.0006	6	1
60	.70711		.70711		1.0000		1.0000		**0**
	Cos.	d.	Sin.	d.	Cot.	d.	Tan.	d.	′

P. P.

45°

TABLE IV

STADIA REDUCTION TABLE

This table is entered with the value of the vertical angle as an argument. The value found in the columns must be multiplied by the stadia intercept.

The values in the columns were computed according to the following formulas.

Upper Part of Table	Lower Part of Table
Hor. dist. $= 100 \cos^2 \alpha$	$(f + c) \cos \alpha$
Hor. cor. $= 100 - 100 \cos^2 \alpha$	$(f + c) - (f + c) \cos \alpha$
Diff. elev. $= 100 \sin \alpha \cos \alpha$	$(f + c) \sin \alpha$

where α = vertical angle

Example of the Use of the Table

Assume

$$f + c = 1.00 \qquad s' = 3.00 \qquad \alpha = 9°00'$$

From the table, for 9°00′

	Hor. Dist.	Hor. Cor.	Diff. Elev.
	97.55	2.45	15.45
C	0.99	0.01	0.16

Method 1:

$$H = 97.55 \times 3.00 + 0.99 = 293.6$$

or

$$H = 300 - (3.00 \times 2.45) + 1.00 - 0.01 = 293.6$$

$$V = 15.45 \times 3.00 + 0.16 = 46.51$$

Method 2:

$$H = 97.55 \times 3.01 = 293.6$$

or

$$H = 301 - (3.01 \times 2.45) \doteq 293.6$$

$$V = 15.45 \times 3.01 = 46.50$$

TABLE IV.[1]—HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS

	0°			1°			2°		
Minutes	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor. Cor.	Diff. Elev.
0	100.00	0.00	0.00	99.97	0.03	1.74	99.88	0.12	3.49
2	100.00	0.00	0.06	99.97	0.03	1.80	99.87	0.13	3.55
4	100.00	0.00	0.12	99.97	0.03	1.86	99.87	0.13	3.60
6	100.00	0.00	0.17	99.96	0.04	1.92	99.87	0.13	3.66
8	100.00	0.00	0.23	99.96	0.04	1.98	99.86	0.14	3.72
10	100.00	0.00	0.29	99.96	0.04	2.04	99.86	0.14	3.78
12	100.00	0.00	0.35	99.96	0.04	2.09	99.85	0.15	3.84
14	100.00	0.00	0.41	99.95	0.05	2.15	99.85	0.15	3.90
16	100.00	0.00	0.47	99.95	0.05	2.21	99.84	0.16	3.95
18	100.00	0.00	0.52	99.95	0.05	2.27	99.84	0.16	4.01
20	100.00	0.00	0.58	99.95	0.05	2.33	99.83	0.17	4.07
22	100.00	0.00	0.64	99.94	0.06	2.38	99.83	0.17	4.13
24	100.00	0.00	0.70	99.94	0.06	2.44	99.82	0.18	4.18
26	99.99	0.01	0.76	99.94	0.06	2.50	99.82	0.18	4.24
28	99.99	0.01	0.81	99.93	0.07	2.56	99.81	0.19	4.30
30	99.99	0.01	0.87	99.93	0.07	2.62	99.81	0.19	4.36
32	99.99	0.01	0.93	99.93	0.07	2.67	99.80	0.20	4.42
34	99.99	0.01	0.99	99.93	0.07	2.73	99.80	0.20	4.48
36	99.99	0.01	1.05	99.92	0.08	2.79	99.79	0.21	4.53
38	99.99	0.01	1.11	99.92	0.08	2.85	99.79	0.21	4.59
40	99.99	0.01	1.16	99.92	0.08	2.91	99.78	0.22	4.65
42	99.99	0.01	1.22	99.91	0.09	2.97	99.78	0.22	4.71
44	99.98	0.02	1.28	99.91	0.09	3.02	99.77	0.23	4.76
46	99.98	0.02	1.34	99.90	0.10	3.08	99.77	0.23	4.82
48	99.98	0.02	1.40	99.90	0.10	3.14	99.76	0.24	4.88
50	99.98	0.02	1.45	99.90	0.10	3.20	99.76	0.24	4.94
52	99.98	0.02	1.51	99.89	0.11	3.26	99.75	0.25	4.99
54	99.98	0.02	1.57	99.89	0.11	3.31	99.74	0.26	5.05
56	99.97	0.03	1.63	99.89	0.11	3.37	99.74	0.26	5.11
58	99.97	0.03	1.69	99.88	0.12	3.43	99.73	0.27	5.17
60	99.97	0.03	1.74	99.88	0.12	3.49	99.73	0.27	5.23
$C = 0.75$	0.75	0.00	0.01	0.75	0.00	0.02	0.75	0.00	0.03
$C = 1.00$	1.00	0.00	0.01	1.00	0.00	0.03	1.00	0.00	0.04
$C = 1.25$	1.25	0.00	0.02	1.25	0.00	0.03	1.25	0.00	0.05

TABLE IV[1].—HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS.—(*Continued*)

	3°			4°			5°		
Minutes	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor. Cor.	Diff. Elev.
0	99.73	0.27	5.23	99.51	0.49	6.96	99.24	0.76	8.68
2	99.72	0.28	5.28	99.51	0.49	7.02	99.23	0.77	8.74
4	99.71	0.29	5.34	99.50	0.50	7.07	99.22	0.78	8.80
6	99.71	0.29	5.40	99.49	0.51	7.13	99.21	0.79	8.85
8	99.70	0.30	5.46	99.48	0.52	7.19	99.20	0.80	8.91
10	99.69	0.31	5.52	99.47	0.53	7.25	99.19	0.81	8.97
12	99.69	0.31	5.57	99.46	0.54	7.30	99.18	0.82	9.03
14	99.68	0.32	5.63	99.46	0.54	7.36	99.17	0.83	9.08
16	99.68	0.32	5.69	99.45	0.55	7.42	99.16	0.84	9.14
18	99.67	0.33	5.75	99.44	0.56	7.48	99.15	0.85	9.20
20	99.66	0.34	5.80	99.43	0.57	7.53	99.14	0.86	9.25
22	99.66	0.34	5.86	99.42	0.58	7.59	99.13	0.87	9.31
24	99.65	0.35	5.92	99.41	0.59	7.65	99.11	0.89	9.37
26	99.64	0.36	5.98	99.40	0.60	7.71	99.10	0.90	9.43
28	99.63	0.37	6.04	99.39	0.61	7.76	99.09	0.91	9.48
30	99.63	0.37	6.09	99.38	0.62	7.82	99.08	0.92	9.54
32	99.62	0.38	6.15	99.38	0.62	7.88	99.07	0.93	9.60
34	99.62	0.38	6.21	99.37	0.63	7.94	99.06	0.94	9.65
36	99.61	0.39	6.27	99.36	0.64	7.99	99.05	0.95	9.71
38	99.60	0.40	6.33	99.35	0.65	8.05	99.04	0.96	9.77
40	99.59	0.41	6.38	99.34	0.66	8.11	99.03	0.97	9.83
42	99.59	0.41	6.44	99.33	0.67	8.17	99.01	0.99	9.88
44	99.58	0.42	6.50	99.32	0.68	8.22	99.00	1.00	9.94
46	99.57	0.43	6.56	99.31	0.69	8.28	98.99	1.01	10.00
48	99.56	0.44	6.61	99.30	0.70	8.34	98.98	1.02	10.05
50	99.56	0.44	6.67	99.29	0.71	8.40	98.97	1.03	10.11
52	99.55	0.45	6.73	99.28	0.72	8.45	98.96	1.04	10.17
54	99.54	0.46	6.78	99.27	0.73	8.51	98.94	1.06	10.22
56	99.53	0.47	6.84	99.26	0.74	8.57	98.93	1.07	10.28
58	99.52	0.48	6.90	99.25	0.75	8.63	98.92	1.08	10.34
60	99.51	0.49	6.96	99.24	0.76	8.68	98.91	1.09	10.40
C = 0.75	0.75	0.00	0.05	0.75	0.00	0.06	0.75	0.00	0.07
C = 1.00	1.00	0.00	0.06	1.00	0.00	0.08	0.99	0.01	0.09
C = 1.25	1.25	0.00	0.08	1.25	0.00	0.10	1.24	0.01	0.11

TABLE IV[1].—HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS.—(*Continued*)

	6°			7°			8°		
Minutes	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor. Cor.	Diff. Elev.
0	98.91	1.09	10.40	98.51	1.49	12.10	98.06	1.94	13.78
2	98.90	1.10	10.45	98.50	1.50	12.15	98.05	1.95	13.84
4	98.88	1.12	10.51	98.48	1.52	12.21	98.03	1.97	13.89
6	98.87	1.13	10.57	98.47	1.53	12.26	98.01	1.99	13.95
8	98.86	1.14	10.62	98.46	1.54	12.32	98.00	2.00	14.01
10	98.85	1.15	10.68	98.44	1.56	12.38	97.98	2.02	14.06
12	98.83	1.17	10.74	98.43	1.57	12.43	97.97	2.03	14.12
14	98.82	1.18	10.79	98.41	1.59	12.49	97.95	2.05	14.17
16	98.81	1.19	10.85	98.40	1.60	12.55	97.93	2.07	14.23
18	98.80	1.20	10.91	98.39	1.61	12.60	97.92	2.08	14.28
20	98.78	1.22	10.96	98.37	1.63	12.66	97.90	2.10	14.34
22	98.77	1.23	11.02	98.36	1.64	12.72	97.88	2.12	14.40
24	98.76	1.24	11.08	98.34	1.66	12.77	97.87	2.13	14.45
26	98.74	1.26	11.13	98.33	1.67	12.83	97.85	2.15	14.51
28	98.73	1.27	11.19	98.31	1.69	12.88	97.83	2.17	14.56
30	98.72	1.28	11.25	98.29	1.71	12.94	97.82	2.18	14.62
32	98.71	1.29	11.30	98.28	1.72	13.00	97.80	2.20	14.67
34	98.69	1.31	11.36	98.27	1.73	13.05	97.78	2.22	14.73
36	98.68	1.32	11.42	98.25	1.75	13.11	97.76	2.24	14.79
38	98.67	1.33	11.47	98.24	1.76	13.17	97.75	2.25	14.84
40	98.65	1.35	11.53	98.22	1.78	13.22	97.73	2.27	14 90
42	98.64	1.36	11.59	98.20	1.80	13.28	97.71	2.29	14.95
44	98.63	1.37	11.64	98.19	1.81	13.33	97.69	2.31	15.01
46	98.61	1.39	11.70	98.17	1.83	13.39	97.68	2.32	15.06
48	98.60	1.40	11.76	98.16	1.84	13.45	97.66	2.34	15.12
50	98.58	1.42	11.81	98.14	1.86	13.50	97.64	2.36	15.17
52	98.57	1.43	11.87	98.13	1.87	13.56	97.62	2.38	15.23
54	98.56	1.44	11.93	98.11	1.89	13.61	97.61	2.39	15.28
56	98.54	1.46	11.98	98.10	1.90	13.67	97.59	2.41	15.34
58	98.53	1.47	12.04	98.08	1.92	13.73	97.57	2.43	15.40
60	98.51	1.49	12.10	98.06	1.94	13.78	97.55	2.45	15.45
C = 0.75	0.75	0.00	0.08	0.74	0.01	0.10	0.74	0.01	0.11
C = 1.00	0.99	0.01	0.11	0.99	0.01	0.13	0.99	0.01	0.15
C = 1.25	1.24	0.01	0.14	1.24	0.01	0.16	1.23	0.02	0.18

TABLE IV[1].—HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS.—(*Continued*)

Minutes	9°			10°			11°		
	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor. Cor.	Diff. Elev.
0	97.55	2.45	15.45	96.98	3.02	17.10	96.36	3.64	18.73
2	97.53	2.47	15.51	96.96	3.04	17.16	96.34	3.66	18.78
4	97.52	2.48	15.56	96.94	3.06	17.21	96.32	3.68	18.84
6	97.50	2.50	15.62	96.92	3.08	17.26	96.29	3.71	18.89
8	97.48	2.52	15.67	96.90	3.10	17.32	96.27	3.73	18.95
10	97.46	2.54	15.73	96.88	3.12	17.37	96.25	3.75	19.00
12	97.44	2.56	15.78	96.86	3.14	17.43	96.23	3.77	19.05
14	97.43	2.57	15.84	96.84	3.16	17.48	96.21	3.79	19.11
16	97.41	2.59	15.89	96.82	3.18	17.54	96.18	3.82	19.16
18	97.39	2.61	15.95	96.80	3.20	17.59	96.16	3.84	19.21
20	97.37	2.63	16.00	96.78	3.22	17.65	96.14	3.86	19.27
22	97.35	2.65	16.06	96.76	3.24	17.70	96.12	3.88	19.32
24	97.33	2.67	16.11	96.74	3.26	17.76	96.09	3.91	19.38
26	97.31	2.69	16.17	96.72	3.28	17.81	96.07	3.93	19.43
28	97.29	2.71	16.22	96.70	3.30	17.86	96.05	3.95	19.48
30	97.28	2.72	16.28	96.68	3.32	17.92	96.03	3.97	19.54
32	97.26	2.74	16.33	96.66	3.34	17.97	96.00	4.00	19.59
34	97.24	2.76	16.39	96.64	3.36	18.03	95.98	4.02	19.64
36	97.22	2.78	16.44	96.62	3.38	18.08	95.96	4.04	19.70
38	97.20	2.80	16.50	96.60	3.40	18.14	95.93	4.07	19.75
40	97.18	2.82	16.55	96.57	3.43	18.19	95.91	4.09	19.80
42	97.16	2.84	16.61	96.55	3.45	18.24	95.89	4.11	19.86
44	97.14	2.86	16.66	96.53	3.47	18.30	95.86	4.14	19.91
46	97.12	2.88	16.72	96.51	3.49	18.35	95.84	4.16	19.96
48	97.10	2.90	16.77	96.49	3.51	18.41	95.82	4.18	20.02
50	97.08	2.92	16.83	96.47	3.53	18.46	95.79	4.21	20.07
52	97.06	2.94	16.88	96.45	3.55	18.51	95.77	4.23	20.12
54	97.04	2.96	16.94	96.42	3.58	18.57	95.75	4.25	20.18
56	97.02	2.98	16.99	96.40	3.60	18.62	95.72	4.28	20.23
58	97.00	3.00	17.05	96.38	3.62	18.68	96.70	4.30	20.28
60	96.98	3.02	17.10	96.36	3.64	18.73	95.68	4.32	20.34
C = 0.75	0.74	0.01	0.12	0.74	0.01	0.14	0.73	0.02	0.15
C = 1.00	0.99	0.01	0.16	0.98	0.02	0.18	0.98	0.02	0.20
C = 1.25	1.23	0.02	0.21	1.23	0.02	0.23	1.22	0.03	0.25

TABLE IV[1].—HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS.—(*Continued*)

	12°			13°			14°		
Minutes	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor. Cor.	Diff. Elev.
0	95.68	4.32	20.34	94.94	5.06	21.92	94.15	5.85	23.47
2	95.65	4.35	20.39	94.91	5.09	21.97	94.12	5.88	23.52
4	95.63	4.37	20.44	94.89	5.11	22.02	94.09	5.91	23.58
6	95.61	4.39	20.50	94.86	5.14	22.08	94.07	5.93	23.63
8	95.58	4.42	20.55	94.84	5.16	22.13	94.04	5.96	23.68
10	95.56	4.44	20.60	94.81	5.19	22.18	94.01	5.99	23.73
12	95.53	4.47	20.66	94.79	5.21	22.23	93.98	6.02	23.78
14	95.51	4.49	20.71	94.76	5.24	22.28	93.95	6.05	23.83
16	95.49	4.51	20.76	94.73	5.27	22.34	93.93	6.07	23.88
18	95.46	4.54	20.81	94.71	5.29	22.39	93.90	6.10	23.93
20	95.44	4.56	20.87	94.68	5.32	22.44	93.87	6.13	23.99
22	95.41	4.59	20.92	94.66	5.34	22.49	93.84	6.16	24.04
24	95.39	4.61	20.97	94.63	5.37	22.54	93.81	6.19	24.09
26	95.36	4.64	21.03	94.60	5.40	22.60	93.79	6.21	24.14
28	95.34	4.66	21.08	94.58	5.42	22.65	93.76	6.24	24.19
30	95.32	4.68	21.13	94.55	5.45	22.70	93.73	6.27	24.24
32	95.29	4.71	21.18	94.52	5.48	22.75	93.70	6.30	24.29
34	95.27	4.73	21.24	94.50	5.50	22.80	93.67	6.33	24.34
36	95.24	4.76	21.29	94.47	5.53	22.85	93.65	6.35	24.39
38	95.22	4.78	21.34	94.44	5.56	22.91	93.62	6.38	24.44
40	95.19	4.81	21.39	94.42	5.58	22.96	93.59	6.41	24.49
42	95.17	4.83	21.45	94.39	5.61	23.01	93.56	6.44	24.55
44	95.14	4.86	21.50	94.36	5.64	23.06	93.53	6.47	24.60
46	95.12	4.88	21.55	94.34	5.66	23.11	93.50	6.50	24.65
48	95.09	4.91	21.60	94.31	5.69	23.16	93.47	6.53	24.70
50	95.07	4.93	21.66	94.28	5.72	23.22	93.45	6.55	24.75
52	95.04	4.96	21.71	94.26	5.74	23.27	93.42	6.58	24.80
54	95.02	4.98	21.76	94.23	5.77	23.32	93.39	6.61	24.85
56	94.99	5.01	21.81	94.20	5.80	23.37	93.36	6.64	24.90
58	94.97	5.03	21.87	94.17	5.83	23.42	93.33	6.67	24.95
60	94.94	5.06	21.92	94.15	5.85	23.47	93.30	6.70	25.00
C = 0.75	0.73	0.02	0.16	0.73	0.02	0.17	0.73	0.02	0.19
C = 1.00	0.98	0.02	0.22	0.97	0.03	0.23	0.97	0.03	0.25
C = 1.25	1.22	0.03	0.27	1.21	0.04	0.29	1.21	0.04	0.31

TABLE IV[1].—HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS.—(*Continued*)

Minutes	15° Hor. Dist.	15° Hor. Cor.	15° Diff. Elev.	16° Hor. Dist.	16° Hor. Cor.	16° Diff. Elev.	17° Hor. Dist.	17° Hor. Cor.	17° Diff. Elev.
0	93.30	6.70	25.00	92.40	7.60	26.50	91.45	8.55	27.96
2	93.27	6.73	25.05	92.37	7.63	26.55	91.42	8.58	28.01
4	93.24	6.76	25.10	92.34	7.66	26.59	91.39	8.61	28.06
6	93.21	6.79	25.15	92.31	7.69	26.64	91.35	8.65	28.10
8	93.18	6.82	25.20	92.28	7.72	26.69	91.32	8.68	28.15
10	93.16	6.84	25.25	92.25	7.75	26.74	91.29	8.71	28.20
12	93.13	6.87	25.30	92.22	7.78	26.79	91.26	8.74	28.25
14	93.10	6.90	25.35	92.19	7.81	26.84	91.22	8.78	28.30
16	93.07	6.93	25.40	92.15	7.85	26.89	91.19	8.81	28.34
18	93.04	6.96	25.45	92.12	7.88	26.94	91.16	8.84	28.39
20	93.01	6.99	25.50	92.09	7.91	26.99	91.12	8.88	28.44
22	92.98	7.02	25.55	92.06	7.94	27.04	91.09	8.91	28.49
24	92.95	7.05	25.60	92.03	7.97	27.09	91.06	8.94	28.54
26	92.92	7.08	25.65	92.00	8.00	27.13	91.02	8.98	28.58
28	92.89	7.11	25.70	91.97	8.03	27.18	90.99	9.01	28.63
30	92.86	7.14	25.75	91.93	8.07	27.23	90.96	9.04	28.68
32	92.83	7.17	25.80	91.90	8.10	27.28	90.92	9.08	28.73
34	92.80	7.20	25.85	91.87	8.13	27.33	90.89	9.11	28.77
36	92.77	7.23	25.90	91.84	8.16	27.38	90.86	9.14	28.82
38	92.74	7.26	25.95	91.81	8.19	27.43	90.82	9.18	28.87
40	92.71	7.29	26.00	91.77	8.23	27.48	90.79	9.21	28.92
42	92.68	7.32	26.05	91.74	8.26	27.52	90.76	9.24	28.96
44	92.65	7.35	26.10	91.71	8.29	27.57	90.72	9.28	29.01
46	92.62	7.38	26.15	91.68	8.32	27.62	90.69	9.31	29.06
48	92.59	7.41	26.20	91.65	8.35	27.67	90.66	9.34	29.11
50	92.56	7.44	26.25	91.61	8.39	27.72	90.62	9.38	29.15
52	92.53	7.47	26.30	91.58	8.42	27.77	90.59	9.41	29.20
54	92.49	7.51	26.35	91.55	8.45	27.81	90.55	9.45	29.25
56	92.46	7.54	26.40	91.52	8.48	27.86	90.52	9.48	29.30
58	92.43	7.57	26.45	91.48	8.52	27.91	90.48	9.52	29.34
60	92.40	7.60	26.50	91.45	8.55	27.96	90.45	9.55	29.39
C = 0.75	0.72	0.03	0.20	0.72	0.03	0.21	0.72	0.03	0.23
C = 1.00	0.96	0.04	0.27	0.96	0.04	0.28	0.95	0.05	0.30
C = 1.25	1.20	0.05	0.34	1.20	0.05	0.35	1.19	0.06	0.38

TABLE IV[1].—HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS.—(*Continued*)

Minutes	18°			19°			20°		
	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor Cor	Diff. Elev.
0	90.45	9.55	29.39	89.40	10.60	30.78	88.30	11.70	32.14
2	90.42	9.58	29.44	89.36	10.64	30.83	88.26	11.74	32.18
4	90.38	9.62	29.48	89.33	10.67	30.87	88.23	11.77	32.23
6	90.35	9.65	29.53	89.29	10.71	30.92	88.19	11.81	32.27
8	90.31	9.69	29.58	89.26	10.74	30.97	88.15	11.85	32 32
10	90.28	9.72	29.62	89.22	10.78	31.01	88.11	11.89	32.36
12	90.24	9.76	29.67	89.18	10.82	31.06	88.08	11.92	32.41
14	90.21	9.79	29.72	89.15	10 85	31.10	88.04	11.96	32.45
16	90.18	9.82	29.76	89.11	10.89	31.15	88.00	12.00	32.49
18	90.14	9.86	29.81	89.08	10.92	31.19	87.96	12.04	32.54
20	90.11	9.89	29.86	89.04	10.96	31.24	87.93	12.07	32.58
22	90.07	9.93	29.90	89.00	11.00	31.28	87.89	12.11	32.63
24	90.04	9.96	29.95	88.96	11.04	31.33	87.85	12.15	32.67
26	90.00	10.00	30.00	88.93	11.07	31.38	87.81	12.19	32.72
28	89.97	10.03	30.04	88.89	11.11	31.42	87.77	12.23	32.76
30	89.93	10.07	30.09	88.86	11.14	31.47	87.74	12.26	32.80
32	89.90	10.10	30.14	88.82	11.18	31.51	87.70	12.30	32.85
34	89.86	10.14	30.19	88.78	11.22	31.56	87.66	12.34	32.89
36	89.83	10.17	30.23	88.75	11.25	31.60	87.62	12.38	32.93
38	89.79	10.21	30.28	88.71	11.29	31.65	87.58	12.42	32.98
40	89.76	10.24	30.32	88.67	11.33	31.69	87.54	12.46	33.02
42	89.72	10.28	30.37	88.64	11.36	31.74	87.51	12.49	33.07
44	89.69	10.31	30.41	88.60	11.40	31.78	87.47	12.53	33.11
46	89.65	10.35	30.46	88.56	11.44	31.83	87.43	12.57	33.15
48	89.61	10.39	30.51	88.53	11.47	31.87	87.39	12.61	33.20
50	89.58	10.42	30.55	88.49	11.51	31.92	87.35	12.65	33.24
52	89.54	10.46	30.60	88.45	11.55	31.96	87.31	12.69	33.28
54	89.51	10.49	30.65	88.41	11.59	32.01	87.27	12.73	33.33
56	89.47	10.53	30.69	88.38	11.62	32.05	87.24	12.76	33.37
58	89.44	10.56	30.74	88.34	11.66	32.09	87.20	12.80	33.41
60	89.40	10.60	30.78	88.30	11.70	32.14	87.16	12.84	33.46
C = 0.75	0.71	0.04	0.24	0.71	0.04	0.25	0.70	0.05	0.26
C = 1.00	0.95	0.05	0.32	0.94	0.06	0.33	0.94	0.06	0.35
C = 1.25	1.19	0.06	0.40	1.18	0.07	0.42	1.17	0.08	0.44

TABLE IV[1].—HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS.—(*Continued*)

Minutes	21° Hor. Dist.	21° Hor. Cor.	21° Diff. Elev.	22° Hor. Dist.	22° Hor. Cor.	22° Diff. Elev.	23° Hor. Dist.	23° Hor. Cor.	23° Diff. Elev.
0	87.16	12.84	33.46	85.97	14.03	34.73	84.73	15.27	35.97
2	87.12	12.88	33.50	85.93	14.07	34.77	84.69	15.31	36.01
4	87.08	12.92	33.54	85.89	14.11	34.82	84.65	15.35	36.05
6	87.04	12.96	33.59	85.85	14.15	34.86	84.61	15.39	36.09
8	87.00	13.00	33.63	85.80	14.20	34.90	84.57	15.43	36.13
10	86.96	13.04	33.67	85.76	14.24	34.94	84.52	15.48	36.17
12	86.92	13.08	33.72	85.72	14.28	34.98	84.48	15.52	36.21
14	86.88	13.12	33.76	85.68	14.32	35.02	84.44	15.56	36.25
16	86.84	13.16	33.80	85.64	14.36	35.07	84.40	15.60	36.29
18	86.80	13.20	33.84	85.60	14.40	35.11	84.35	15.65	36.33
20	86.77	13.23	33.89	85.56	14.44	35.15	84.31	15.69	36.37
22	86.73	13.27	33.93	85.52	14.48	35.19	84.27	15.73	36.41
24	86.69	13.31	33.97	85.48	14.52	35.23	84.23	15.77	36.45
26	86.65	13.35	34.01	85.44	14.56	35.27	84.18	15.82	36.49
28	86.61	13.39	34.06	85.40	14.60	35.31	84.14	15.86	36.53
30	86.57	13.43	34.10	85.36	14.64	35.36	84.10	15.90	36.57
32	86.53	13.47	34.14	85.31	14.69	35.40	84.06	15.94	36 61
34	86.49	13.51	34.18	85.27	14.73	35.44	84.01	15.99	36.65
36	86.45	13.55	34.23	85.23	14.77	35.48	83.97	16.03	36.69
38	86.41	13.59	34.27	85.19	14.81	35.52	82.93	16.07	36.73
40	86.37	13.63	34.31	85.15	14.85	35.56	83.89	16.11	36.77
42	86.33	13.67	34.35	85.11	14.89	35.60	83.84	16.16	36.80
44	86.29	13.71	34.40	85.07	14.93	35.64	83.80	16.20	36 84
46	86.25	13.75	34.44	85.02	14.98	35.68	83.76	16.24	36.88
48	86.21	13.79	34.48	84.98	15.02	35.72	83.72	16.28	36.92
50	86.17	13.83	34.52	84.94	15.06	35.76	83.67	16.33	36.96
52	86.13	13.87	34.57	84.90	15.10	35.80	83 63	16.37	37.00
54	86.09	13.91	34.61	84.86	15.14	35.85	83.59	16.41	37.04
56	86.05	13.95	34.65	84.82	15.18	35.89	83.54	16.46	37.08
58	86.01	13.99	34.69	84.77	15.23	35.93	83.50	16.50	37.12
60	85.97	14.03	34.73	84.73	15.27	35.97	83.46	16.54	37.16
C = 0.75	0.70	0.05	0.27	0.69	0.06	0.29	0.69	0.06	0.30
C = 1.00	0.93	0.07	0.37	0.92	0.08	0.38	0.92	0.08	0.40
C = 1.25	1.16	0.09	0.46	1.15	0.10	0.48	1.15	0.10	0.50

TABLE IV[1].—HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS.—(*Continued*)

	24°			25°			26°		
Minutes	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor. Cor.	Diff. Elev.
0	83.46	16.54	37.16	82.14	17.86	38.30	80.78	19.22	39.40
2	83.41	16.59	37.20	82.09	17.91	38.34	80.74	19.26	39.44
4	83.37	16.63	37.23	82.05	17.95	38.38	80.69	19.31	39.47
6	83.33	16.67	37.27	82.01	17.99	38.41	80.65	19.35	39.51
8	83.28	16.72	37.31	81.96	18.04	38.45	80.60	19.40	39.54
10	83.24	16.76	37.35	81.92	18.08	38.49	80.55	19.45	39.58
12	83.20	16.80	37.39	81.87	18.13	38.53	80.51	19.49	39.61
14	83.15	16.85	37.43	81.83	18.17	38.56	80.46	19.54	39.65
16	83.11	16.89	37.47	81.78	18.22	38.60	80.41	19.59	39.69
18	83.07	16.93	37.51	81.74	18.26	38.64	80.37	19.63	39.72
20	83.02	16.98	37.54	81.69	18.31	38.67	80.32	19.68	39.76
22	82.98	17.02	37.58	81.65	18.35	38.71	80.28	19.72	39.79
24	82.93	17.07	37.62	81.60	18.40	38.75	80.23	19.77	39.83
26	82.89	17.11	37.66	81.56	18.44	38.78	80.18	19.82	39.86
28	82.85	17.15	37.70	81.51	18.49	38.82	80.14	19.86	39.90
30	82.80	17.20	37.74	81.47	18.53	38.86	80.09	19.91	39.93
32	82.76	17.24	37.77	81.42	18.58	38.89	80.04	19.96	39.97
34	82.72	17.28	37.81	81.38	18.62	38.93	80.00	20.00	40.00
36	82.67	17.33	37.85	81.33	18.67	38.97	79.95	20.05	40.04
38	82.63	17.37	37.89	81.28	18.72	39.00	79.90	20.10	40.07
40	82.58	17.42	37.93	81.24	18.76	39.04	79.86	20.14	40.11
42	82.54	17.46	37.96	81.19	18.81	39.08	79.81	20.19	40.14
44	82.49	17.51	38.00	81.15	18.85	39.11	79.76	20.24	40.18
46	82.45	17.55	38.04	81.10	18.90	39.15	79.72	20.28	40.21
48	82.41	17.59	38.08	81.06	18.94	39.18	79.67	20.33	40.24
50	82.36	17.64	38.11	81.01	18.99	39.22	79.62	20.38	40.28
52	82.32	17.68	38.15	80.97	19.03	39.26	79.58	20.42	40.31
54	82.27	17.73	38.19	80.92	19.08	39.29	79.53	20.47	40.35
56	82.23	17.77	38.23	80.87	19.13	39.33	79.48	20.52	40.38
58	82.18	17.82	38.26	80.83	19.17	39.36	79.44	20.56	40.42
60	82.14	17.86	38.30	80.78	19.22	39.40	79.39	20.61	40.45
C = 0.75	0.68	0.07	0.31	0.68	0.07	0.32	0.67	0.08	0.33
C = 1.00	0.91	0.09	0.41	0.90	0.10	0.43	0.89	0.11	0.45
C = 1.25	1.14	0.11	0.52	1.13	0.12	0.54	1.12	0.13	0.56

TABLE IV[1].—HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS.—(*Continued*)

	27°			28°		
Minutes	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor. Cor.	Diff. Elev.
0	79.39	20.61	40.45	77.96	22.04	41.45
2	79.34	20.66	40.49	77.91	22.09	41.48
4	79.30	20.70	40.52	77.86	22.14	41.52
6	79.25	20.75	40.55	77.81	22.19	41.55
8	79.20	20.80	40.59	77.77	22.23	41.58
10	79.15	20.85	40.62	77.72	22.28	41.61
12	79.11	20.89	40.66	77.67	22.33	41.65
14	79.06	20.94	40.69	77.62	22.38	41.68
16	79.01	20.99	40.72	77.57	22.43	41.71
18	78.96	21.04	40.76	77.52	22.48	41.74
20	78.92	21.08	40.79	77.48	22.52	41.77
22	78.87	21.13	40.82	77.43	22.57	41.81
24	78.82	21.18	40.86	77.38	22.62	41.84
26	78.77	21.23	40.89	77.33	22.67	41.87
28	78.73	21.27	40.92	77.28	22.72	41.90
30	78.68	21.32	40.96	77.23	22.77	41.93
32	78.63	21.37	40.99	77.18	22.82	41.97
34	78.58	21.42	41.02	77.13	22.87	42.00
36	78.54	21.46	41.06	77.09	22.91	42.03
38	78.49	21.51	41.09	77.04	22.96	42.06
40	78.44	21.56	41.12	76.99	23.01	42.09
42	78.39	21.61	41.16	76.94	23.06	42.12
44	78.34	21.66	41.19	76.89	23.11	42.15
46	78.30	21.70	41.22	76.84	23.16	42.19
48	78.25	21.75	41.26	76.79	23.21	42.22
50	78.20	21.80	41.29	76.74	23.26	42.25
52	78.15	21.85	41.32	76.69	23.31	42.28
54	78.10	21.90	41.35	76.64	23.36	42.31
56	78.06	21.94	41.39	76.59	23.41	42.34
58	78.01	21.99	41.42	76.55	23.45	42.37
60	77.96	22.04	41.45	76.50	23.50	42.40
C = 0.75	0.66	0.09	0.35	0.66	0.09	0.36
C = 1.00	0.89	0.11	0.46	0.88	0.12	0.48
C = 1.25	1.11	0.14	0.58	1.10	0.15	0.60

TABLE IV[1].—HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS.—(*Concluded*)

	29°			30°		
Minutes	Hor. Dist.	Hor. Cor.	Diff. Elev.	Hor. Dist.	Hor. Cor.	Diff. Elev.
0	76.50	23.50	42.40	75.00	25.00	43.30
2	76.45	23.55	42.43	74.95	25.05	43.33
4	76.40	23.60	42.46	74.90	25.10	43.36
6	76.35	23.65	42.49	74.85	25.15	43.39
8	76.30	23.70	42.53	74.80	25.20	43.42
10	76.25	23.75	42.56	74.75	25.25	43.45
12	76.20	23.80	42.59	74.70	25.30	43.47
14	76.15	23.85	42.62	74.65	25.35	43.50
16	76.10	23.90	42.65	74.60	25.40	43.53
18	76.05	23.95	42.68	74.55	25.45	43.56
20	76.00	24.00	42.71	74.49	25.51	43.59
22	75.95	24.05	42.74	74.44	25.56	43.62
24	75.90	24.10	42.77	74.39	25.61	43.65
26	75.85	24.15	42.80	74.34	25.66	43.67
28	75.80	24.20	42.83	74.29	25.71	43.70
30	75.75	24.25	42.86	74.24	25.76	43.73
32	75.70	24.30	42.89	74.19	25.81	43.76
34	75.65	24.35	42.92	74.14	25.86	43.79
36	75.60	24.40	42.95	74.09	25.91	43.82
38	75.55	24.45	42.98	74.04	25.96	43.84
40	75.50	24.50	43.01	73.99	26.01	43.87
42	75.45	24.55	43.04	73.93	26.07	43.90
44	75.40	24.60	43.07	73.88	26.12	43.93
46	75.35	24.65	43.10	73.83	26.17	43.95
48	75.30	24.70	43.13	73.78	26.22	43.98
50	75.25	24.75	43.16	73.73	26.27	44.01
52	75.20	24.80	43.18	73.68	26.32	44.04
54	75.15	24.85	43.21	73.63	26.37	44.07
56	75.10	24.90	43.24	73.58	26.42	44.09
58	75.05	24.95	43.27	73.52	26.48	44.12
60	75.00	25.00	43.30	73.47	26.53	44.15
C = 0.75	0.65	0.10	0.37	0.65	0.10	0.38
C = 1.00	0.87	0.13	0.49	0.86	0.14	0.51
C = 1.25	1.09	0.16	0.62	1.08	0.17	0.64

[1] In part from "Theory and Practice of Surveying," by Prof. J. B. Johnson; John Wiley & Sons, Inc., New York.

LIST OF VISUAL AIDS

The following visual aids may be found useful in presenting the material covered in this text. These filmstrips can be obtained from the source listed or in many cases they can be borrowed from your nearest film library.

FILMSTRIPS

Army Pictorial Service, Motion Picture Branch, The Pentagon, Washington 25, D. C.

Surveying: Measuring and Leveling (FS 5-76).
Surveying: Traversing (FS 5-77).
Surveying: Building and Utility Lay-out (FS 5-78).
The Transit, Part 1: Description Setup and Leveling (FS 6-33).
The Transit, Part 2: Verniers (FS 6-34).
The Use of the Transit (FS 4-192).
The Transit Traverse: Organization and Duties of the Party (FS 4-195).

W. & L. E. Gurley, Troy, N. Y.

The Construction of the Engineer's Transit
The Transit, Its Care, Cleaning and Lubrication

DISPLAYS, CHARTS AND LITHOGRAPHS

Keuffel & Esser Co., Adams and Third Sts., Hoboken, N. J.

Vernier Display (A large board with movable parts showing the operation of several straight verniers and one transit vernier.)

C. L. Berger & Sons, Inc., 37 Williams St., Boston 19, Mass.

Surveying Instruments (A chart showing enlarged cross sectional views of Surveying Instruments.)

Buff & Buff Mfg. Co., Jamaica Plain, Mass.

A Transit (A large colored lithograph of a transit.)

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